How the F-22 Will Rule the Skies

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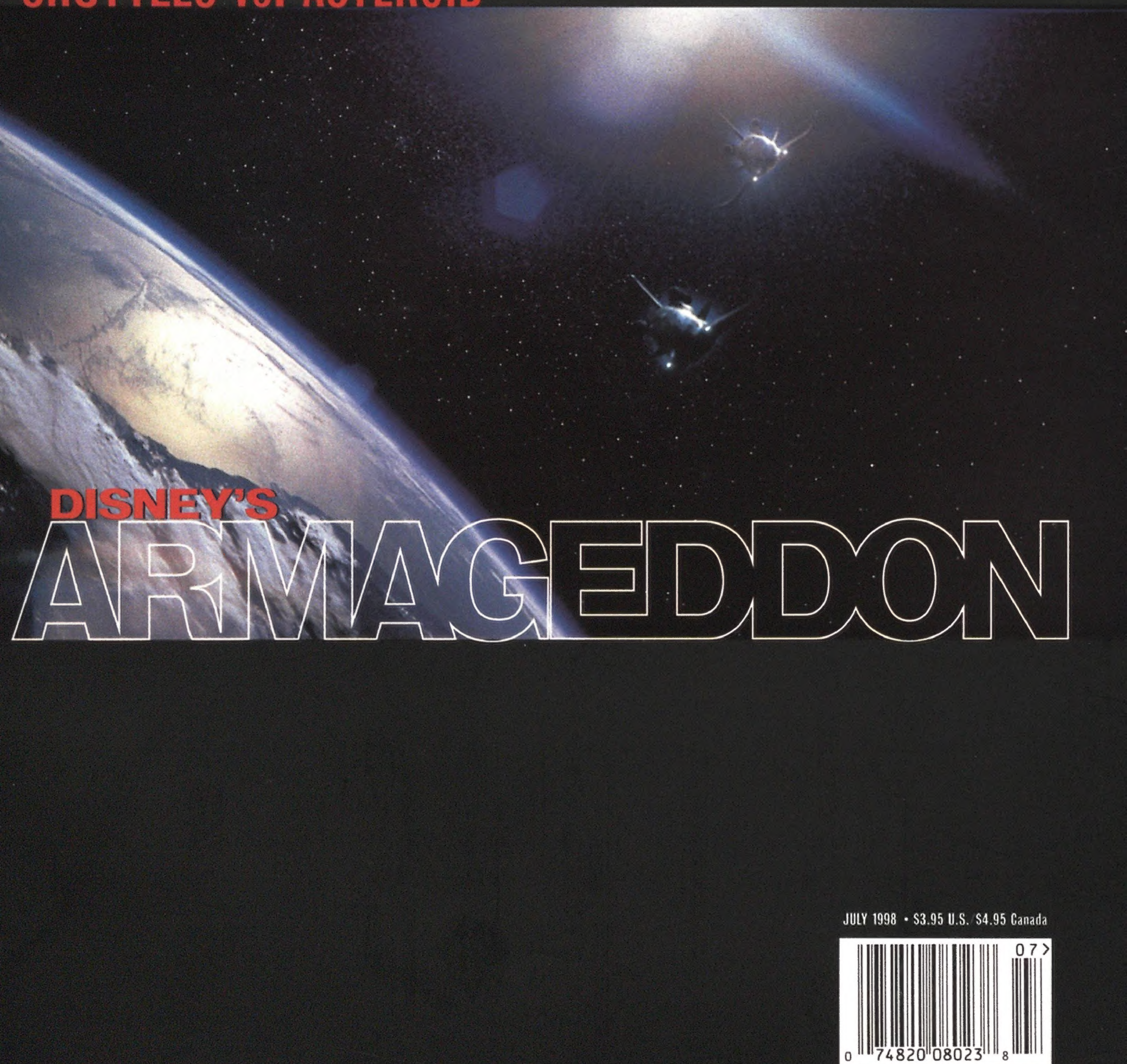
SHUTTLES vs. ASTEROID



DISNEY'S ARMAGEDDON

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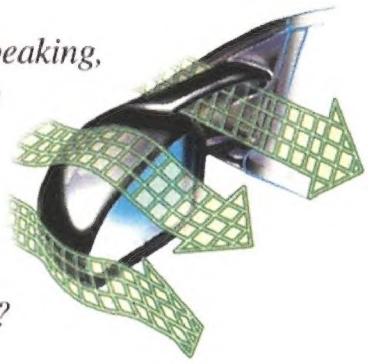
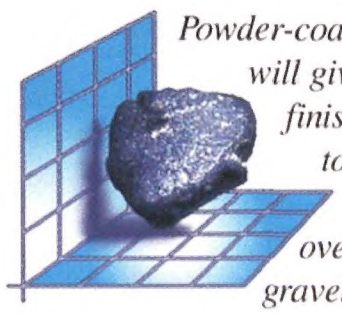
Aerodynamically speaking, a Dodge Stratus is one slippery car. Is it possible to see the future, then, in the rear-view mirror?



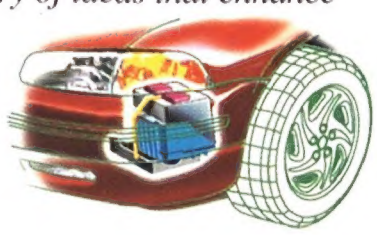
Dodge pioneered the cab-forward design concept – moving the wheels out to the corners and sliding the passenger compartment forward. Can cab-forward roominess create more room even in the trunk?

You'd expect a race car to be graded on a curve. Well, if race cars inspired us to modify a double-wishbone suspension, can you handle it?



Powder-coat paint technology will give you a paint finish tough enough to help protect a car's shiny overcoat from flying gravel. When it comes to what you'll expect down the road, do we have things pretty well covered?

It's a simple engineering principle: lose weight, gain performance. But can a whole battery of ideas that enhance performance include simply moving the battery?



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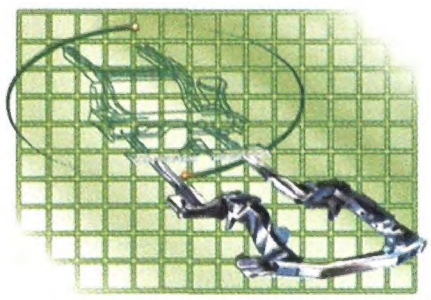
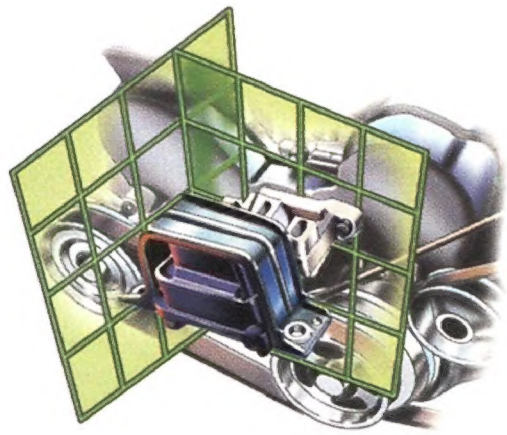
Car chassis have traditionally been built on a "floor pan" design. Can a platform that incorporates a continuous rigid, ladder-type frame improve ride and handling characteristics? Can this help us reach a high level of performance?



Let's see, there's more room up front. There's more room in back. Is everyone comfortable with cab-forward?

Take something as simple as an engine mount – a combination of steel and rubber that holds the engine to the frame rail. Can we mount a good argument that a device filled with liquid could minimize engine vibration and help make things quieter?



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Remember a backseat is the safest place for children.

This is the answer.

Stratus The New Dodge

June/July 1998
Volume 13, Number 2

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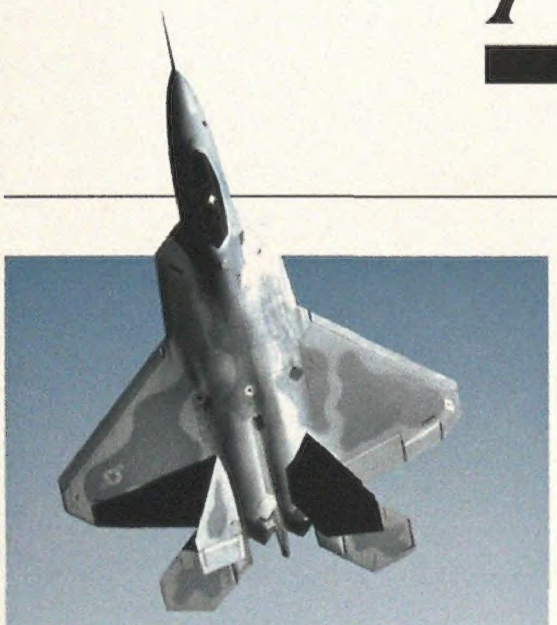

The 21st Century Fighter by Fred Reed

A look at the technological innovations that place the F-22 Raptor at the top of the aviation food chain.

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Super shuttles to the rescue!
Armageddon
photo courtesy Touchstone Pictures and Jerry Bruckheimer, Inc.

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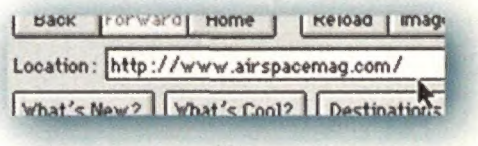

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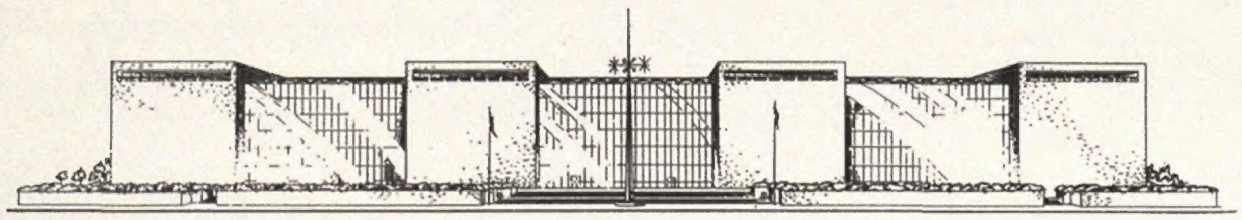

Glass Wear

It was a summer evening in 1996 and two hundred formally attired guests were seated at tables in the National Air and Space Museum's Pioneers of Flight gallery enjoying a dinner in honor of an aviation luminary. One of those late-summer thunderstorms had been putting on a brilliant display of lightning and was now in the process of dumping rainwater at a prodigious rate. Although no one in attendance was expecting it, nature was about to demonstrate the need for long-planned improvement to the Museum.

As the host for the event, I had a sense of foreboding, and I wasn't paying much attention to my meal. I was worried about the glass ceiling. It was prone to leak, and its past history told me we would probably experience one, but I was not sure where—or when. Suddenly, one of our guests let out a shriek.

Sure enough, rainwater had leaked through the ceiling and pooled on the polymer-covered wing of Paul MacCready's human-powered Gossamer Condor, which was hanging overhead. When the wing could no longer contain this Colorado River, Lake Mead poured over the trailing edge. With unerring accuracy the rainwater poured directly down the low-cut dress and back of a very nice and important lady, thus eliciting a long and excruciatingly sharp scream. My "fix" was to rise quickly and move the table and eight guests a few feet back. We also moved one of our buckets, kept nearby for such occurrences, to catch the rest of the water.

This is my way of explaining that we have long needed to replace ceiling and window glass and to perform related repair work in the Museum. Over the past 22 years the sealant around the glass has dried and the double-glass thermal panes have lost their effectiveness as an insulating barrier.

This year we begin what will be a three-year effort, but we'll do it with a minimum of discomfort to our visitors. As you can imagine, there is a tremendous amount of planning that must be done to protect the air- and spacecraft that will remain on display while the work takes place.

During the planning and preparation we have received a great amount of attention from the Fine Arts Commission and others as we selected—and then had to re-select—the appropriate shade of glass. The Museum curators would like non-light-transmitting glass, as in "black," to protect the fabric covering of airplanes and spacesuits from light damage. The Fine Arts Commission would like clear glass, as in "see-through." After countless meetings and discussions, we selected glass of just the right shade to let our visitors feel that the Museum is open and spacious, yet prevent damage to the artifacts.

This summer we will begin work. We have found a way to enable the contractor to move around the Museum in an orderly fashion without forcing us to close the entire building. We will close only a few galleries at a time, and visitors will see images of Wilbur and Orville Wright, both wearing hard hats, with labels nearby to explain the work in progress.

First to close temporarily will be the Sea-Air, World War II, Golden Age of Flight, and *Enola Gay* galleries in the western end of the Museum. The effort will be like a gigantic game of musical chairs, because we will reopen three of those first four galleries before moving on to others. In order to complete the project, we must use the *Enola Gay* gallery and one other as working spaces.

Originally, the *Enola Gay* gallery was scheduled to be open for six months. But the gallery has now been open for almost three years, and many millions of visitors have seen it. The B-29, some parts of which serve as the gallery's centerpiece, will be completely assembled and the airplane displayed in its entirety in our new Dulles Center, which is being designed and will be built before the end of 2001. I will tell you more about this entirely new part of the National Air and Space Museum later this year.

—Don Engen is director of the National Air and Space Museum.

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LETTERS

Midway: Can't We All Get Along?

I was pleased when writer Bill Marsano and photographer Caroline Sheen visited Midway Atoll National Wildlife Refuge last summer. But Bill's article, "The Battle of Midway, Part II" (Apr./May 1998), missed the mark. His basic premise, that "commerce and wildlife are in 180-degree opposition," reveals that he did not understand the unique nature of this project. Commerce in the form of wildlife-oriented tourism is indeed critical to the success of our wildlife management efforts at Midway. While we might disagree on some details, the Fish and Wildlife Service and its cooperator, Midway Phoenix Corporation, are focused on the same objective: a compatible public use program.

The article also leaves the reader with the impression that the Fish and Wildlife Service is not committed to the preservation and interpretation of Midway's valuable historical resources. Nothing could be further from the truth. In the short time we have managed the facility, we have invested heavily in the protection and restoration of important historic structures, most of which were in very poor condition when the Navy left. We have also embarked on an ambitious program to share Midway's historic legacy with our refuge visitors.

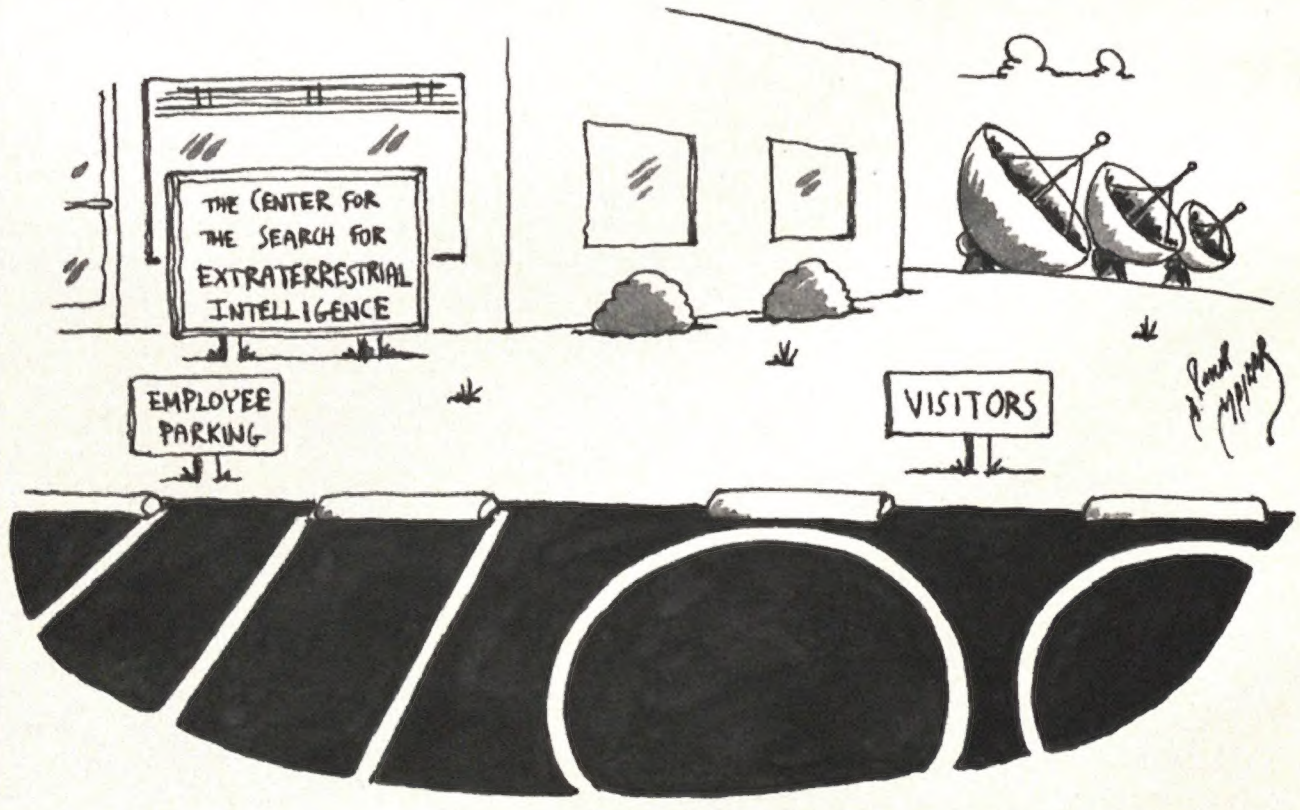
Midway is a very special place. We hope your readers will come see for themselves.

—Robert Shallenberger
Refuge Manager
Midway Atoll National Wildlife Refuge

On what basis does the U.S. Fish and Wildlife Service designate verbesina and ironwood as "alien"? Just because these plants weren't part of Midway's ecosystem in 1941? Or in 1981? Perhaps the service should also destroy every species of bird and other fauna that wasn't on Midway back then.

Any plant or animal species that can thrive in a particular area has as much right to be called indigenous as any other, regardless of how or when it arrived there.

—Keith A. Mount
Martinsville, New Jersey



A Forgotten Flying Wing

In response to Robert Wagner's inquiry (Letters, Dec. 1997/Jan. 1998), the United Kingdom did experiment with flying wings after World War II. One was an airplane called the Armstrong Whitworth AW52 [above]. I saw it fly from Farnborough on several occasions.

—David N. Johns
Hampshire, England

Take Your Toys and Go Home

I was pleased to learn that the Jet Propulsion Laboratory was making money from the production of Mars Rover models ("Toy Story," Soundings, Feb./Mar. 1998). However, I was disappointed that the models were being produced in China. With so many jobs being lost as companies move production facilities overseas, it would seem prudent for a government agency not to encourage this trend.

—Col. Warren G. Campbell (ret.)
U.S. Air Force
Corvallis, Oregon

Joan Horvath, Business Alliances Manager for JPL, responds: JPL's contract with NASA requires licensees (who are actually licensees of the California Institute of Technology, which operates JPL) to be U.S. companies, to manufacture substantially in the United States, or to be explicitly granted an exception. In the case of the Mars Rover models, Mattel certified that manufacturing die-cast toys in the United States was not economically feasible, so the company was granted an exception.

A Special Plea

I am looking for some World War II logbooks kept by my father, Ken Rawles. He started service in the Royal Air Force as a sergeant and later became a flight lieutenant. During the war he was the central figure in a poster that became well known in England; it was captioned "Never was so much owed by so many to so few."

My father died in 1980, and the following year my mother donated his RAF logbooks to the Tangmere Military Aviation Museum in Sussex, England. Early this year I wrote to Tangmere asking if I could photocopy the books, and it was then I learned that no one had seen them for years. The chairman of the present trust and the curator believe that the books disappeared in the early days of the museum, perhaps sold off.

I am told that this sort of memorabilia is quite as likely to have gone to a collector in the United States as to one in

England. I would be most grateful if someone out there could help me.

I must make it plain that anyone who has bought them in good faith need not fear litigation by my family. I would simply like to copy the books for the information.

—June Harvey
Tower Farm, Tower Cross
Honiton, East Devon EX14
England

Offensive Letters

In his attempt at humor ("Gone but Not Remembered," Feb./Mar. 1998), Bruce McCall commits an intolerable insult: Drawing a Czech airplane marked with Russian letters. Czechs have been an integral part of Western European culture, economy, and politics for more than a thousand years, and they have always used the Latin alphabet. Ever since Joseph Stalin was handed the Central European nations as a gift after World War II, Western "experts" have been advocating an attachment of these nations to the Soviet colonial empire. McCall happily follows in their footsteps.

Isn't half a century of insults piled on injuries enough?

K.A. Skapa
Denver, Colorado

I'm afraid I've finally come across a letter to the editor I wish I hadn't bothered to read: Sean Casey's response in the last issue to "Gone but Not Remembered." Mr. Casey just doesn't get it. Bruce McCall is a genius, a killer combination of humorist and illustrator. I hope we see more of his work in *Air & Space.*

—Frank Whitney
Watervliet, New York

Lessons of the Arrow

Cancellation or reduction of expensive programs like aircraft development is criminal. In the case of the Arrow, cancelling the program left Canadian taxpayers with huge development costs and little to show for them ("Fallen Arrow," Apr./May 1998). Often more than half the cost of a new program is getting the first aircraft airborne. The cost of producing the remainder of the airframes is but a minor portion of the contract price. No wonder the B-2 is so expensive: They built only a few rather than the hundred originally planned.

—Ray Stark
Carefree, Arizona

Secrets of the Iron Maiden

For many years, I was in charge of U.S. Air Force research on the effects of sustained acceleration on pilot physiology, workload capacity, cognitive function, and the like, as well as development of protective methodologies and equipment. I was surprised to read that the Naval Air Development Center in Warminster, Pennsylvania, had apparently passed on the Iron Maiden to the Pax River museum ("Remembrances of Things Pax," Collections, Apr./May 1998) without telling the museum staff what the vessel actually was.

The Iron Maiden was built at Warminster (then called Johnsville) in the 1950s to investigate a way to protect the wearer from G-forces. The test subject was provided with the equivalent of scuba gear and sealed into the vessel. The vessel was then filled with water and the man subjected to sustained acceleration on a giant centrifuge. The breathing gas

pressure supplied to him was always equivalent to the pressure exerted on his body by the liquid filling the vessel.

The test program was a great success, but the practicality of applying this technology in a fighter aircraft or a spacecraft was an embarrassing stumbling block.

—R.E. van Patten
Bellbrook, Ohio

Very Bigfoot

The text on the opening pages of "Bigfoot" (Feb./Mar. 1998) describes the Boeing 777's landing gear as having 12 tires, but the picture on those pages shows an airplane with 16 tires. Which is it?

—Robert D. Lederer
Monroe, Connecticut

Editors' reply: The airplane in the photograph is a Boeing 747 and was not meant to illustrate the article's opening scene.

Defending Yeager

Scott Crossfield's remark about Chuck Yeager ("Mach Two Times," Soundings, Apr./May 1998) is typical of the arrogant, high-priced (some might say over-priced) NACA help of the time. The attitude seems to be: "How dare some insignificant Air Force captain beat us to Mach 1?"

Col. R.J. Powers (ret.)
U.S. Air Force
Shreveport, Louisiana

He's No Muscle Man

"Rockets for the Rest of Us" (Feb./Mar. 1998) refers to John McCaw as the "financial muscle" behind Kistler Aerospace Corporation. In fact, Mr. McCaw is one of many valued investors who collectively provide the financial muscle behind the company.

—Robert Wang, Chairman of the Board
Kistler Aerospace Corp.
Los Angeles, California

Spirit of St. Louis, Fully Loaded

Would it be impolite to correct director Don Engen's assertion that the National Air and Space Museum displays the *Spirit of St. Louis* "as it was" when it flew to Paris ("A 70-Year Question," Viewport, Feb./Mar. 1998)? After that flight, the airplane underwent several modifications: Before Lindbergh's July 1927 National Tour, louvers were added to the removable metal nose panels, and parachute flare tubes were installed prior to the December 1927 Latin American Tour.

—Kenneth Taylor
Los Osos, California

Correction

Apr./May 1998 "The Outer Limits": The opening illustration should have shown the planets orbiting counterclockwise.

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Snow Job

AIR TRACTOR

DAVID LEESON

When Leland Snow flew into Olney, Texas, in early 1958, his future depended on making a good impression. A prototype of his new cropduster, the S-2, had crashed just weeks earlier, and Snow was almost broke. He needed a factory, operating capital, and enough cash to certify the S-2, and Olney was interested in helping.

But as Snow touched down at Olney's airport after a long flight from the Rio Grande Valley, the reception committee noticed something odd. The landing gear, it seemed, didn't match.

"I was trying to finish up the cropdusting season, and I had a big split in one of the two tires, and the tube was starting to come through the split," Snow recalls. "I finally chickened out. I rushed over to the Harlingen airport and looked in the junk heap out back. I found a smaller wheel and tire. I put it on the plane and it worked. I finished the season and planned to put on a new tire, but I never got around to it."

Olney forgave the oversight. Local businessmen guaranteed a loan for operating capital and residents chipped in $45,000 to build a factory. The Snow Aeronautical Company moved from Harlingen to Olney, a farming and ranching town on the rolling prairie west of Fort Worth, in January 1958 and began building the world's first aircraft designed specifically for cropdusting.

On a gorgeous day last March, much of Olney turned out to celebrate the 40-year partnership at Snow's present company, Air Tractor. (He sold Snow Aeronautical to Rockwell-Standard in 1965 and started Air Tractor after Rockwell moved cropduster production to Georgia.)

Five beefy yellow and blue Air Tractors gleamed in the sun on the ramp outside the factory doors, and visitors climbed up to peek in the cockpits. Snow's wife, Nancy, dressed in Air Tractor-yellow jacket and beret, mingled with guests while his daughters, who handle much of the company's daily operations, kept the festivities moving along. And in a brief speech, Snow recalled how his mother used her car as collateral to finance the S-1.

Snow, who soloed on his 16th birthday, began cropdusting at age 21. "There were only converted Stearmans or Pipers, which were not well suited to this kind of work," said the soft-spoken pilot. "I wanted to do something with my training [as an aeronautical engineer], so in June of 1951 I started building my first airplane."

For two years, Snow flew the S-1 to Nicaragua after the Texas dusting season. He made some money, showed the airplane to other pilots, and had a few adventures. One day he was over Lake Managua when he realized the cap on the left wing tank was on backward and fuel was streaming out. He climbed out on the wing, held on to the cockpit, and turned the cap around.

Other pilots liked the S-1, so Snow started developing the all-metal S-2 for commercial production—until Halloween 1957, when he flight tested the wing's load-bearing capacity. The left wing spar broke, the wing snapped off, and Snow passed out when the airplane went into a high-G spin. He recovered in time to bail out and watch the S-2 plunge into the south Texas mud flats.

Snow overcame the design flaw and sold his first S-2s in 1958. Since then, Snow Aeronautical and Air Tractor have sold more than 2,100 airplanes. Today, Air Tractor makes more single-engine turboprops than any other manufacturer and produces the world's largest, the 16,000-pound AT-802.

Air Tractor also sells a firefighting version of the 802, and from his home office in Wichita Falls, Snow is designing an even larger version. He dreams of building a small freighter or a new bushplane to replace aging de Havilland Beavers and Otters. "I like work airplanes," he says. "That's what I do—I build work airplanes." With matching wheels, of course.

—Damond Benningfield

UPDATE

Jet Engine Co-Inventor Dies

Hans von Ohain, co-inventor of the jet engine ("Gentlemen, I Give You the Whittle Engine," Oct./Nov. 1992), died in Melbourne, Florida, last March 13 at the age of 86. His engine was responsible for the first jet-powered flight, in a Heinkel 178, in August 1939. After World War II von Ohain moved to the United States, signed on as a research scientist at Wright Field in Dayton, Ohio, and worked for the U.S. government for 32 years. In 1991, he and Sir Frank Whittle received the National Academy of Engineering's Charles Stark Draper prize as co-inventors of the aviation gas turbine.

Turn-On

At 11:45 on the morning of April 2, a call echoed down the corridors at the Bethesda, Maryland headquarters of Wingspan, a new cable television channel devoted to aviation and space: "Everyone at Wingspan, to the board room." The voice of Carole Osborne, wife of the channel's founder, Phil Osborne, sounded like a schoolmarm's over the PA system.

Employees, most in their 20s and wearing big metal buttons saying "I Was There at the Launch," began to gather in the tiny windowless space, where a video cameraman recorded events and a video monitor, now dark, awaited the moment when the channel would go on the air for the first time. Flashbulbs popped and the noise in the room rose as champagne was uncorked. Osborne, together with Walter Boyne, president of Wingspan, a former director of the National Air and Space Museum, and founder of this magazine, shook hands and gabbed with the staff. "Bristol is on line," shouted someone, and with that, the channel's news desk in England came on over an audio speaker.

Following calls of "quiet, quiet," Osborne thanked everyone for the five years of effort that had led up to the launch of the channel and reflected on the occasional advice that the whole thing was a "bad idea." Instead, he said, it had been a "fascinating challenge." Programming includes global aerospace news from worldwide bureaus and interview shows hosted by Boyne. But the heart of Wingspan will be its documentary footage combined with narratives that recall the aircraft, airlines, and battles throughout the history of flight.

Then, at exactly noon, to a chorus counting down "five, four, three, two, one," the monitor glowed, and Wingspan was on the air with a story about a Rolls-Royce engine that will power a new Airbus model. Initially distributed through Media General, a cable operator in Northern Virginia, the channel plans to expand its coverage via satellite distribution.

—George C. Larson

CAROLINE SHEEN

Strings Attached

National Park Service ranger Dave Rappel was on the lookout for killer kites. The National Air and Space Museum's March 28 kite festival on the Mall in Washington, D.C., had been threatened by rogue kiters who might attack at any moment. But an anxious public had other concerns.

"Where are the bathrooms?"

"Are there any public restrooms?"

"We need to find a bathroom quick. We have a three-year-old...."

Rappel addressed each question as if hearing it for the first time. "Well, yes," he said. "If you go over to the other side of the monument, we have a lodge there with restrooms. And you could, if you want to walk that far, go over to the Smithsonian museums." Then he went back to scanning the sky.

Rappel and the other rangers had been told at a morning staff meeting to be on the lookout for anyone cutting the strings of the glorious creations at the annual festival. Concern had grown after an official of the American Kitefliers Association reported a group of men flying distinctive home-made kites of tissue and twigs had attacked his expensive kite one weekend, severing the line and sending it into a jarring collision with a tree. The attackers, who use imported line coated with powdered glass, came to the Washington Monument to fight each other with their kites, but for some reason had attacked a noncombatant. "It's like walking up behind someone and smacking them in the head," association regional director Jon Burkhardt said. "This is not a contest. This is cruel."

Rappel said the rangers didn't have a specific description of the suspects. "We are to look out for anything odd about the lines, such as something coated with shards of glass."

Inside the park service lodge, site manager Erin Broadbent watched for danger from her office window. "All I see is lots of cheap dime-store kites attached to little squealing bodies," she said. "There's not a killer kite in sight." All in all, Broadbent said, it was a Fourth of July kind of day.

And then the word came. A young woman raced into the lodge. "They're cutting the kite lines," she said, catching her breath. "There are two kids doing it. There's a blue and yellow box kite in a tree. They told me to tell you."

On the other side of the grounds, under a press tent, kite festival spokeswoman Meg Pearson was calm. "False alarm," she said. "It was just the usual lines crossed. No indication of an attack." Pearson had said that the kite killers wouldn't dare disrupt the festival. She was right.

—Linda Wheeler

UPDATE

New Racers at Reno

North American T-28s and high-performance kit-built aircraft will debut as new classes at this year's Reno Air Races ("Gentlemen, You Have a Race," Apr./May 1997). The Sport Racing class will "highlight the new and innovative work being done in the development of high-performance kit-built aircraft," says air race chairman Jack Walther. Maximum engine size is 650 cubic inches. The T-28 Trojan, a trainer built in the 1950s and powered by an 800-horsepower Wright R-1300 engine, will round out the high-horsepower roster, augmenting the T-6 and Unlimited classes.

Heavy Metal

For Sale: Aircraft carrier. 31,850 tons, 911-foot-long flight deck. 192 feet from waterline to top of mast. Veteran of Korean and Vietnam Wars. Contact the Department of Defense regarding the USS Oriskany.

"If we decide to bid on the carrier and it is delivered to our facility in Brownsville, Texas, our yard workers would use natural-gas torches to carve the vessel into 10,000- to 40,000-pound sections, and then cut those sections into two- by five-foot strips," says Michael C. Donovan, a director of International Shipbreaking Limited. "Next we usually sell the high-grade ferrous scrap to what are called minimills, located in Gulf Coast states and Mexico." Last August, Donovan and some 30 other ship scrappers were at the Mare Island Naval Facility in California, touring the USS *Oriskany*, the last Essex-class aircraft carrier the Navy built. The rights to scrap the ship were being sold by the Defense Reutilization and Marketing Service, the Department of Defense branch charged with selling the Navy's growing inventory of decommissioned warships.

"This isn't the first aircraft carrier I've bid on," says Joe D'Alessio, president of Norfolk Recycling, a ship-scrapping firm. "Once this friend asked me to oversee the construction of a toxic waste treatment plant and hazardous waste dump in Panama." At the time D'Alessio worked as a consultant for Resource Recovery International, the company contracted to build the facility in Panama. "But the construction site was in the middle of a jungle near the coast," D'Alessio says. "We had no place to house our crew. So my friend and I decided to bid on a mothballed carrier to use as a living and work space for the men."

In January 1991 the DRMS held a sealed-bid auction in which Resource Recovery bid $200,000 for the decommissioned carrier USS *Bennington*. "Lo and behold, we get a call in about a week that we were the successful bidders," D'Alessio says. "We figured, Man, our troubles are over."

But D'Alessio's troubles were just beginning. The following year the U.S. government convicted General Manuel Noriega, Panama's leader at the time, on drug trafficking charges. D'Alessio says that Noriega's conviction and the ensuing political instability doomed the construction project and left Resource Recovery stuck with an aircraft carrier. But the company went on to sell the *Bennington* to a middleman in England, who subsequently sold the carrier to an Indian ship-scrapping firm for a reported $6 million.

The *Oriskany* almost received a second life in 1992, when City of America Foundation, a Japanese corporation, planned to pay an estimated $2.5 million for the carrier and convert it to a museum in Yokohama highlighting American culture and technology. But the company backed away from the purchase after its fundraising efforts stalled.

"The bottom line," D'Alessio says as he disembarks the *Oriskany*, "is that somebody's going to tear this ship down and make some money."

—*Lane D. Barnholtz*

To Boldly Go Where No Hair Has Gone Before

Did you miss that offer to send your signature to Saturn for free aboard NASA's Cassini probe? Having trouble scraping together the $4,800 to have your ashes launched into orbit?

Lucky you. Here's another chance to experience space: For $50 you can send your DNA out of the solar system to celebrate the new millennium.

The mission is Encounter 2001, brought to you in part by Celestis Inc. of Houston, which pioneered space burials. Celestis executive Charles Chafer heads up the commercial enterprise to launch hair samples from 4.5 million people into interstellar space.

This is your chance "to seek a little bit of immortality, have a little bit of fun, and possibly," says Chafer, "just possibly, be involved in the first contact with another civilization." And you can do it without breaking the bank. "A family of four will spend 50 bucks going to a *Star Trek* movie," he points out.

Encounter 2001 had 40 reservations before the company even began advertising last April. They include a pregnant woman who bought slots for four generations plus the child she's carrying, and Alan Ladwig, chief of plans and policy at NASA, who, with his wife, was first in line.

For $50 you get a membership kit with a poster, a patch, a lapel pin, a certificate with your flight reservation, an "archival document," and a plastic bag in which to mail your hair to Encounter 2001.

"Your job as a participant is to supply us with six hairs, with the root intact," Chafer says. Yank them out, make sure each has a little bulb on the end—that's the root—and stuff them in the bag. On the document, tape down your mug shot and then express your humanity in the blank space provided.

You may submit poetry, prose, musical score, or artwork—with or without a hair sample. Anything goes, as long as you do it in black ink or pencil and you stay within the lines.

The documents go to a Massachusetts company that scans them onto a CD hardened to withstand radiation. The hair goes to a California laboratory that uses a process called vacuum distillation to dry and package the roots in batches of 10,000.

The hair will be loaded into a microsatellite, built by AeroAstro LLC, that is designed to ride piggyback with one or two larger communications satellites on an Ariane 5 rocket. After launch in 2001, it will hover in geosynchronous orbit as long as eight months, waiting for Earth and Jupiter to align themselves just right. Then the craft will fire its motor, escape Earth's gravity, and use Jupiter's gravity to fling itself out of the solar system. In

DAVID PETERS

the meantime, Chafer says Encounter 2001 is busy paving the way with radio messages, the first of which will be broadcast next New Year's Eve to parts of the cosmos "where we think there is a decent chance that there are extrasolar planets." The transmission, from a rented dish, will include names of participants, a description of the spacecraft, and the tease "Ready or not, here we come."

The spacecraft will carry a binary-encoded "Rosetta stone" telling what's inside and how to use it in case it's ever intercepted. "Presumably, somebody sophisticated enough to encounter it would be able to figure out the digital technology," Chafer says.

—Beth Dickey

UPDATE

Bogus Parts Blamed for Death

A former helicopter parts dealer in New Zealand was convicted on manslaughter charges, fined $13,000, and sentenced to three years in prison last December after selling counterfeit tail rotor blades for a Robinson R-22 ("Search and Destroy: The War on Counterfeit Parts," Oct./Nov. 1996). James Edward Gedson had salvaged blades from a demolished R-22, had them remanufactured by Cherry Air Specialties in California, then installed them on another R-22 and sold the craft. The two buyers were killed in 1995 when one of the blades disintegrated and caused the helicopter to crash and burn.

Park Service Goes Under

This year's mega-hit *Titanic* has soaked up more than its share of publicity lately. Even the staid Society for American Archaeology jumped on board. Capitalizing on the shipwreck craze, the society sponsored a public lecture at Seattle's Museum of Flight last March, where Daniel J. Lenihan, chief of the National Park Service's Submerged Cultural Resources Unit, gave a presentation on World War II and postwar underwater sites.

Postwar clean-up, economic progress, and the passage of time have all but eliminated most war-related sites on land. But underwater objects deteriorate more slowly. "The World War II ships and aircraft at the bottom of the Pacific Ocean lie where they fell," said Lenihan. "They

LARRY MURPHY/NPS

have not passed through the artificial filter of a museum, so archaeologists can study them in their original historical context."

A few years after its formation in 1980, SCRU was asked to map the USS *Arizona* and the USS *Utah*, both casualties of the attack on Pearl Harbor. The *Arizona* carried 1,177 men to their graves—half of the fatalities that occurred that day. "Think of mapping an object about three times the size of the Statue of Liberty," said Lenihan. "Then imagine doing that when the visibility is extremely poor—about five to seven feet."

The Pearl Harbor project was low on tech and high on diving. The SCRU team, assisted by other park service and Navy personnel, made about 600 dives over a total of six weeks. Underwater housing for video cameras had just come on the market, and the resulting footage was a bonanza for the media. Other than the video cameras, though, Lenihan and his crew used string, measuring tape, clothes pins, and dime-store protractors. (Only the outside of the vessel was surveyed; the interior is considered a war grave.) "We used the string to divide the ship into 10 sections underwater, each approximately 60 feet long," said Lenihan. "We treated each section like a horizontal plane, despite the ship's curvatures, finishing one section at a time before moving on. Each evening we'd work out closures on all the angles and see what didn't fit. Then our illustrator would work out the mathematics as best he could."

One of the first discoveries was that the *Arizona*'s forward turret was still intact, a surprise to both the Navy and the park service. Both thought the forward turret had been removed earlier with the other turrets to form shore batteries.

The team also determined what actually sank the battleship. "Many people that day—people who were in a position to know—thought they saw a torpedo strike the ship," said Lenihan, "but our underwater research confirmed it was an armor-piercing aerial bomb."

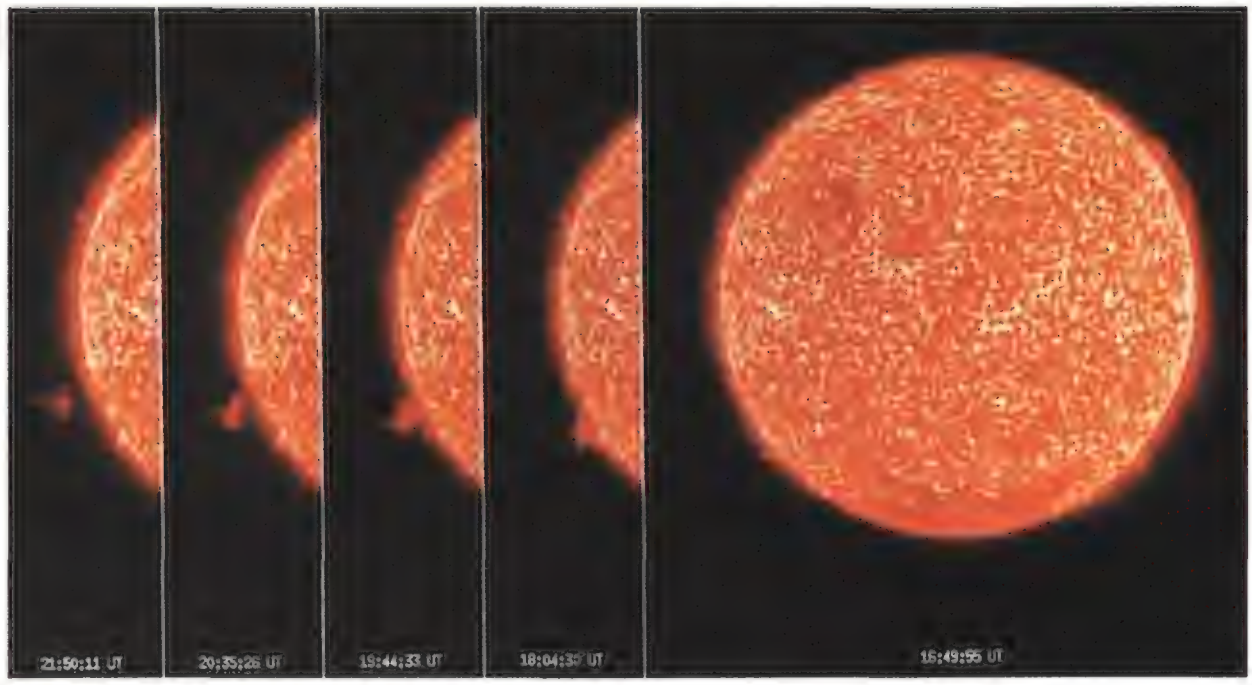
SCRU's Pearl Harbor work resulted in detailed maps and reports. A model of the *Arizona*, produced a few years later, is now on display at the memorial site. Monitoring continues today. "Pollution has become a concern," said Lenihan. "We are seeing minor increases in oil leaking from places on the ship where the bunkers were compromised. No one is certain how much oil is left." Lenihan will collect more data from the site this summer.

SCRU also played a key role in mapping six ships sunk in the Bikini Atoll during Operation Crossroads. "In 1946 the U.S. government detonated the fourth and fifth atomic bombs at Bikini just to see what these nuclear devices would do," said Lenihan. "In 1989 the Department of Energy asked us to assess the condition of some of these vessels."

The focus was on the aircraft carrier *Saratoga*, which had seen action earlier at Iwo Jima. It was 180 feet down in the comparatively sheltered waters of the Bikini Atoll lagoon. The ship had been sunk, fueled and armed, with four Curtiss Helldivers still on its hangar deck, bomb racks at the ready. At 890 feet, the *Saratoga* holds the record for the biggest underwater object ever mapped. Said Lenihan, "Visually, it was one of the most stunning sights I have ever seen."

—Rita Cipalla

NASA



Fried Green Satellites

Mystical millennium predictions aside, there is at least one troublesome cosmic event beginning in the year 2000: the next solar maximum, or solar max, the peak of the 11-year sunspot cycle. The solar El Niño could cause occasional havoc on Earth by disrupting essential communications technologies.

Solar max is part of a natural cycle of solar activity that has played regularly for millions of years, marked by a peak in the number of sunspots, dark islands of highly magnetic gases that erupt on the star's surface. That increase is accompanied by larger and more frequent emissions of these plasmas and streams of electromagnetic particles. The peak lasts two or three years.

For most of human history, the only Earthly effects of the solar max were brilliant auroral displays created when an intense burst of solar particles sweeping by Earth interacts with the planet's magnetic field near the poles. But as humans began using the electromagnetic spectrum, solar max became increasingly more disruptive. During World War II one solar eruption briefly knocked out all high-frequency radio traffic in England. In 1989, during the last solar max, a power grid voltage regulator in Quebec, Canada, was blown out by a magnetic storm. The outage lasted days and cost the local utility company $10 million.

The next solar cycle could be much more disruptive, some scientists predict, because telecommunications technologies have grown more vulnerable to its effects, and private industry is launching satellites at an unprecedented rate.

"Their satellites are at risk because most of the integrated circuits aren't radiation-hardened," says Richard Behnke, a physicist with the National Science Foundation in Arlington, Virginia. Behnke, who leads the interagency National Space Weather Program, explains that newer satellites employ sophisticated electronic technologies that can easily be damaged or destroyed by high-energy solar particles. One solution is to invest extra money and payload weight in proper shielding, but that's not a top priority in today's competitive environment. Behnke likens the situation to companies building flimsy beachfront condominiums in an area frequented by hurricanes.

Joe Allen, a physicist with the Commerce Department's National Geophysical Data Center in Boulder, Colorado, agrees. "Every time a component or circuit is made smaller and faster it becomes more vulnerable to space weather." Allen, who has been studying space weather and its potential for damage to satellites for 25 years, predicts the next solar max could produce a large number of dangerous electromagnetic storms, perhaps the most ever recorded.

"Nobody can afford to admit they're vulnerable," says Thomas Tascione, a former Air Force space weather specialist now with a private forecasting company in Omaha, Nebraska. "The business is too competitive." Yet vulnerable they are. "I haven't found a company yet that doesn't have a problem," he says.

On the other hand, he adds, the dangers from magnetic storms will tend to be highly localized, more like lightning strikes or tornadoes than hurricanes. Tascione and others divide the major difficulties into two areas: space-based and ground-based.

In space, streams of protons and electrons produced by solar disturbances can create powerful static electricity buildup both outside and inside satellites, especially those in geostationary orbits, about 23,000 miles up. The high orbits, outside the protective Van Allen radiation belts, leave satellites wide open to the brief but powerful particle streams. And the resulting static discharges, can, on rare occasions, kill satellites.

That's what experts believe happened to a Canadian communications satellite in 1994 when it encountered such a particle stream spawned by a solar flare. Another failure occurred last fall aboard an Indian telecommunications satellite, although the cause has not been verified. And a solar storm is believed to have disabled a Chinese satellite last March.

"We do occasionally have difficulties," admits John Evans, chief technical officer of COMSAT Corporation in Bethesda, Maryland. But overall, he says, the commercial satellite industry's record of satellite reliability is exemplary. And with 35 years of experience, including three full solar cycles, "the industry is about as well prepared as it can be."

Ground-based problems occur when solar max effects disrupt telecommunications signals. A magnetic storm last fall generated a disturbance in Earth's ionosphere over the Caribbean Sea that interfered with signals from Global Positioning System satellites, says Michael Kelley, a space scientist with Cornell University.

That's worrisome, Kelley says, because faulty GPS readings could have dangerous consequences if users are unaware of ionospheric conditions. The airline industry, for one, is becoming increasingly reliant on GPS for navigation, including airport approaches and landings.

The electric power industry likewise could have serious problems, much more so than it experienced during the last solar max. Since the industry is so heavily interconnected now, Tascione explains, ground current buildup—a common phenomenon in higher latitudes during magnetic storms—could trigger widespread power outages.

—Phil Berardelli

UPDATE

Russian Rocket Engines

Kistler Aerospace conducted a successful test-firing of a modified NK-33 rocket engine last March ("Rockets for the Rest of Us," Feb./Mar. 1998). Designed in the 1960s to power the mammoth Russian N-1 launcher, the NK-33s were selected by Kistler to power its K-1 reuseable launcher. Modified by GenCorp Aerojet, the engine was run for 145 seconds and varied in thrust from 177,000 to 354,000 pounds.

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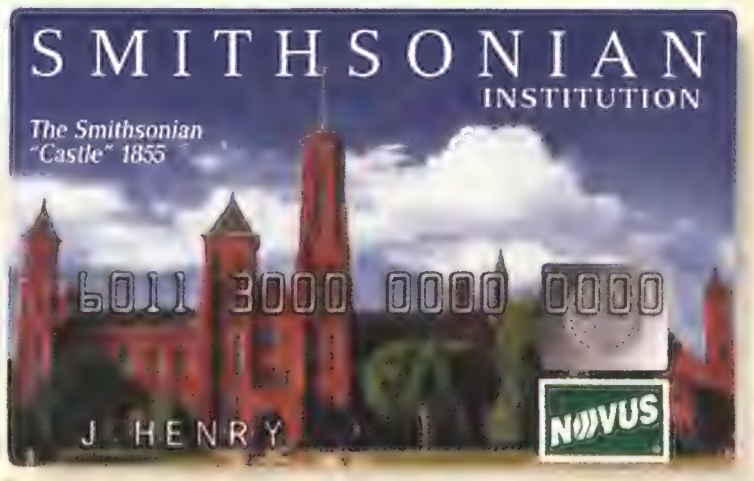

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The Airship That Charmed Paris

NASM (2)

My colleagues at the National Air and Space Museum are an extraordinarily knowledgeable bunch, but I would wager a considerable sum that not one of them can answer this simple question: What was the first successful, full-scale, powered aircraft to be accepted into the Smithsonian collection?

The answer: Airship Number 9, designed, built, and flown by the Brazilian aeronautical pioneer Alberto Santos-Dumont.

I hasten to admit that this is something of a trick question. Accessioned by the U.S. National Museum on March 16, 1907, the airship (most of it, at any rate) was destroyed five years later. Today, all that remains is its engine, displayed in the Early Flight gallery.

Airship Number 9 was powered by a two-cylinder, air-cooled Clement that developed 3.5 horsepower. That doesn't sound like much, but it was enough to drive a diminutive Brazilian pilot and his favorite airship back and forth above the rooftops of Paris while the world watched in delight.

Alberto Santos-Dumont stabled Baladeuse at a hangar in the suburb of St. Cloud (top). In addition to airships, Santos experimented with other craft, like the wingless float hydroplane above.

Alberto Santos-Dumont, the son of a wealthy coffee planter, arrived in Paris in 1892 as an 18-year-old engineering student. Most aviation history buffs know him as the pilot who in 1906 made the first public flight in Europe in a heavier-than-air craft—his airplane *14-bis*. But Monsieur Santos, as he preferred to be addressed, started his aviation career with lighter-than-air vehicles. He was fascinated by ballooning and acquired his first, *Brazil*, in 1898. He grew dissatisfied with the free balloon's limitations, however, and later that year produced the first of what would be 12 powered airships.

Santos made headlines around the world on October 19, 1901, when he flew his airship Number 6 seven miles from his hangar in the Paris suburb of St. Cloud to the Eiffel Tower and back in less than half an hour. Awarded the 100,000-franc Deutsch de la Meurthe Prize for the feat, he divided one-quarter of the money among his mechanics and donated the rest to the poor people of Paris. Santos became the toast of the city.

A man of striking appearance, he stood five feet five in the shiny patent leather boots that he ordered specially fitted with lifts. Dark hair, parted sharply in the middle and held in place with a thick coat of pomade, capped a face that was almost cadaverously thin. Those who knew him observed that the faintly comic appearance of his jug-handle ears, long nose, bristling mustache, and heavily lidded eyes was more than offset by a cool, patrician manner.

But Santos could feel great affection for

his inventions; in later years, he remarked that his favorite airship was Number 9, which he nicknamed Baladeuse, "the little runabout." First flown in the spring of 1903, Baladeuse was small for an airship, 36 feet long and with a maximum diameter of 11½ feet. The Clement engine drove the craft through the air at a top speed of 12 to 15 mph.

To fly the airship Santos employed a technique that involved allowing part of a 132-foot rope to trail on the ground as a means of maintaining a constant altitude. If the airship dipped lower, additional rope would trail on the ground, lightening the weight carried by the airship and slowing its descent. If Baladeuse rose, it would lift the weight of additional line, slowing the ascent. In this fashion, Santos cruised up and down the major boulevards of Paris at an altitude of less than 100 feet, usually in the early morning hours when the traffic was light. During one flight in June 1903, Santos descended into the middle of a crowd gathered for a children's fair at Bagatelle. Instantly surrounded by noisy youngsters, he asked if any child wanted to go up in his airship. Clarkson Potter, the seven-year-old son of an American diplomat, was treated to the ride of his young life.

Santos allowed only one individual other than himself to make a solo flight with Baladeuse. Aïda D'Acosta, a member of an old Cuban family that had settled in New York, first appeared at Santos' airship hangar in June 1903. "Having visited my station with her friends on several occasions, [D'Acosta] confessed an extraordinary desire to navigate the airship," Santos recounted in his memoir, *My Airships*. Santos gave her three days of lessons, and then, on June 29, 1903, let her solo. Her trip, of roughly one mile, made her not only the first American, but also the first woman, to solo a powered flying machine (another bit of trivia likely to stump aviation buffs).

So how did the historic airship wind up at the Smithsonian? In 1904, Santos sold Number 9 to a wealthy New Yorker named Edward C. Boyce, who agreed to donate it to the Smithsonian. After some long delays the airship arrived, but there were problems. In order to fit the crate into a freight car, railroad officials had cut it into two pieces, damaging and jumbling many of the parts. When a Smithsonian employee sorted everything out, he noted that the gasbag, propeller, rudder parts, and other items where missing.

After several months of fingerpointing, legal threats, and general confusion, the missing items were discovered in a large warehouse in New York City. In the summer of 1908 the missing parts were finally shipped to the Smithsonian, but the confusion had taken its toll on the airship's fragile rubber gasbag. Four years later a Smithsonian curator decided that the airship was worthless and recommended that it be destroyed. Only the engine was saved. Today it is the sole reminder to visitors that the Smithsonian was once the proud possessor of a Santos-Dumont original.

—Tom Crouch

GIFT BOX

GEORGE C. LARSON

In a ceremony last January, deputy director Donald Lopez (center) accepted on behalf of the Museum a generous donation presented by Pratt & Whitney executives Dennis Grout (left) and Gary Minor (right): Pratt & Whitney's United Technologies division will refurbish many of the engines in the Museum's collection, including some classic Pratt & Whitney radial recips, like the ones shown here. Curators hope to display much of the engine collection near appropriate aircraft when the Museum's Dulles Center opens.

Museum Calendar

June 9 1998 Wernher von Braun Lecture—"The Ultimate High Ground: Space and Our National Security." General Thomas S. Moorman Jr. of the U.S. Air Force will discuss the evolution of space-based intelligence programs and how the use of space has affected the military. Langley Theater, 8 p.m.

June 10 "Climate and Life on Mars." University of Colorado geology professor Bruce Jakosky will discuss the connections between Martian geology and climate. Einstein Planetarium, 7:30 p.m.

New Exhibit "Business Wings," an exhibition on the airplane's role in the business community, opens to the public on June 12. The exhibition, sponsored by the National Business Aviation Association, will run for one year and will feature two aircraft, a Beech King Air Model A90 and a Cessna Citation. Gallery 104.

June 13 & 14 "Wings and Things." Open house at the Paul E. Garber Preservation, Restoration and Storage Facility. Get a look at nearly 150 air- and spacecraft belonging to the National Air and Space Museum but not displayed at the building on the Mall. Call (202) 357-2700 for more information. Suitland, Maryland, 10 a.m. to 3 p.m.

June 27 "Space Station Assembly and Operations." Patrick McCracken of NASA will discuss the international space station. Einstein Planetarium, 6 p.m.

July 4 Concert by the Air Force band. Mall side of Museum, 6 p.m.

National Air and Space Society

As a member of the National Air and Space Society, your support will help the Museum's efforts to build an extension at Dulles International Airport, which will display such artifacts as an SR-71 Blackbird and the space shuttle *Enterprise*. To receive additional information, call (202) 357-3762 or write to the National Air and Space Society, NASM, Room 3608, MRC 310, Washington, DC 20560; e-mail: nass@sivm.si.edu

Escape from Saigon

COURTESY RICHARD A. MACDONALD

Naval message traffic in early 1975 indicated things were going very poorly for the South Vietnamese. Cities and provinces were falling to the North Vietnamese Army. When I read that the NVA was shelling Tan Son Nhut, Saigon's airport, I felt a growing sense of uneasiness. Thousands of Americans and dependents were still in Saigon, yet no one had issued an official order to evacuate.

Late in coming, Operation Frequent Wind—the evacuation of Saigon—began in April when a large number of 7th Fleet ships were called, including the USS *Midway*, where I was assigned as an A-7 Corsair pilot.

As a new squadron member, I was given the task of drawing up flight plans, navigation routes, and maps for possible missions in which our A-7s would protect helicopters during the evacuation. The air wing was told to issue all flight crew members .38-caliber pistols, an item we never flew with during peacetime. There was talk of giving us five-inch Zuni rockets again. These air-to-ground missiles had been banned for causing the terrible fires on the USS *Enterprise* and *Forrestal* in the late 1960s that killed a total of 161 and injured 407.

The pilots' reactions to all of this ranged from the sky-is-falling syndrome to the John Wayne attitude. Personally, I thought we were on a roller-coaster ride, plummeting into another "controlled escalation" war. The older aviators, most of whom had flown combat tours in Vietnam, seemed indifferent, even though most thought the shooting war was starting again. The indifferent approach afforded better mental flexibility, because what was happening wasn't war, or shooting, or anything close. It was chaos.

In early April, the *Midway* was ordered to serve as a floating evacuation platform. We would transfer evacuees from Saigon to our decks by helicopter and then fly them to the Philippines on fixed-wing transports. To make room on the *Midway*'s decks, we started launching fighter and attack jets to the Philippines.

By late April, we had scheduled evacuation flights to Saigon many times, only to have the missions canceled. After days of these on-and-off events, we finally had crews just sitting in their helicopters, waiting. The crews were tasked with being constantly ready to launch and yet never doing so, a situation aviators loathe. As an A-7 pilot with neither an airplane or a mission, I was assigned mountains of paperwork and was continuously busy. The longer the delay before a difficult mission, the more you imagine the worst that can happen. The tension mounts exponentially with each passing hour.

On April 29, 1975, the order to evacuate Saigon was finally issued. Most helicopter pilots and crews aboard the *Midway* had spent the last 24 hours strapped into their aircraft. We began a series of flights to and from Saigon with Navy and Marine helicopter crews flying more hours than they had slept for the past several days. This tempo took its toll. There is a certain look an aviator has when he is beyond bone-tired. Some call it the thousand-yard stare. On those last days of April 1975, all the helicopter pilots had this look to some degree. I felt guilty that I could do nothing to help.

As we started our evacuation flights, Vietnamese National Air Force

helicopters loaded with evacuees arrived unannounced. Among the first of the VNAF arrivals was ex-Premier Nguyen Cao Ky. Carrier air traffic control picked up his pilot's distress call and vectored his helicopter to the *Midway*. After an official greeting by Seventh Fleet flag and staff officers, Ky was reported to have wept for several minutes, possibly because he had recently publicly announced: "Any Vietnamese who deserts his country is a traitor."

Planned and unplanned helicopter arrivals brought people by the hundreds, some of them clinging to the outside of the aircraft. Many Vietnamese evacuated to the *Midway* were neither U.S. citizens nor dependents, but their close ties to the U.S. government during the Vietnam conflict would have meant death once they had been captured by the NVA. Other Vietnamese simply forced their way into evacuation sites and onto helicopters. Many helicopter crews spoke of panic in the crowds at these sites; some crew members had to use brute force to prevent their helos from becoming so overloaded that they'd crash or be unable to lift off. This was particularly true at the U.S. Embassy, where the pilots described the experience as watching a "sugar cube covered with ants." Thus the number of evacuees reaching the *Midway* far exceeded what had been expected.

Our kitchens began around-the-clock operations to feed the arrivals. The lines to the mess decks wound through the hangar deck from fore to aft several times and held hundreds of the hungry and frightened. I walked past those lines many times that day and was deeply affected each time. Everyone that was hungry was fed, but there was little that could be done to raise the spirits of so many weary and terrified people. Most had families and relatives who were facing an unknown fate in Saigon.

During a lull in the waves of helicopters going to and from Saigon, a lone VNAF observation airplane circled the carrier. The Cessna O-1 was a 1950s design built to carry one or two people. Due to either a language problem or a failure of the little aircraft's radio, we could not maintain radio contact. Soon, several small objects were thrown out of the aircraft that either missed the flight deck or rolled off into the sea. Finally, a piece of fruit landed on the deck and was found to contain a note folded inside. The note, in broken English, identified the pilot as a VNAF officer with men, women, and children aboard and stated, "I am a good pilot. I want to land. Can you move the planes?"

From the ship's control tower, I watched the note being passed along the flight deck. Each recipient of the soggy note shrugged his shoulders and handed it to someone of higher rank. Finally, the note arrived in the tower and was handed to the air boss, the senior officer responsible for flight operations. The boss also shrugged and said, "Give this to the captain." A few moments later, the gruff voice of the ship's commanding officer barked over the intercom, "Pull everything forward!" A flurry of activity commenced, with the air boss issuing ear-splitting commands over deck-level loudspeakers. In a few minutes, we had a clear deck.

Seeing the mass of machinery removed from the landing area, the O-1 pilot began an approach. Not realizing the deck of the *Midway* rode some 60 feet above sea level, the O-1 was very low on the first of several attempts to land. Dropping below flight deck level, he wisely elected to add full power, circle the ship, and try again. There were moans from those watching. On one approach, the pilots around me used body English as if by sheer will they could force the little airplane safely on to the deck.

The efforts seemed to take effect and the O-1 landed gently and rolled slowly to a halt—only to begin rolling backward as the stiff wind over the deck caught it. Deck crews frantically threw chocks under the wheels. When it stopped, seven people emerged from the tiny aircraft, both adults and children. The adults were grinning from ear to ear, while the children stared wide-eyed and blank-faced at the immense, gray *Midway*.

As a gesture of goodwill, the entire crew of the *Midway* passed the hat and donated over $7,000 to these very skillful Saigon escapees for their future life in the United States.

The helicopter flights finally ended late on April 29. Berthing spaces were at a premium even before the influx. In contrast to today's super-carriers, the ship had a small number of personnel, usually only 3,500. With several thousand evacuees aboard during the peak of Operation Frequent Wind, we almost doubled the ship's normal population.

The problem of where to put all these people until they could be airlifted to the Philippines and the States became a monumental headache. Ordinary bunk rooms filled up fast, leaving many Navy personnel to sleep in noisy repair shops, ready rooms, and passageways. Next, storage rooms were used to house the arrivals, and finally even heads—bathrooms—were converted to temporary living spaces. Families were kept together whenever possible. I'll never forget the sight of children running and playing or the sound, so intensely out of place aboard a naval warship, of infants crying at night.

—Richard A. Macdonald

NATIONAL MUSEUM OF NAVAL AVIATION

During the April 1975 evacuation of Saigon, the pilot of a Cessna beseeched the USS Midway *to let him land on its crowded flight deck (opposite, pictured with VNAF aircraft picked up at Utapao, Thailand). After a successful landing, the South Vietnamese Air Force pilot was surrounded by happy crewmen (above).*

The pilot of the O-1 was South Vietnamese Air Force Major Bung Ly; with him were his wife and five children. The O-1 is now in the National Museum of Naval Aviation at Pensacola, Florida.

Walk This Way

The foil-clad bulk of an Apollo lunar lander stands before me. Beyond it stretches an expanse of craters and rocks, brilliantly illuminated under a pitch-black sky. What my eyes tell me is too good to be true: I am on the moon. Suddenly a voice rings out: "Will everyone please clear the lunar surface? We need to get everyone off the lunar surface."

The voice belongs to the assistant director of Tom Hanks' 12-part miniseries for HBO, *From the Earth to the Moon*. I am at the Marine Air Station in Tustin, California, in a cavernous space that was once a blimp hangar. A small army of actors, directors, and production people is filming the series' moonwalk sequences. They have crafted a moonscape out of 38,000 square feet of crushed granite, and on it they have perched a replica of an Apollo lander. It's lit by a bank of xenon spotlights producing a total of 210,000 watts and focused on a single convex mirror that mimics the blinding sunlight of space.

Being here is more than a chance to engage in some lunar sightseeing. As the author of *A Man on the Moon*, a history of the Apollo project that I spent eight years writing, I have been closely involved in the series since its inception.

In 1995 Hanks called me to say he was cooking up a miniseries that would tell the human stories behind Apollo. He'd earned a reputation as Hollywood's space enthusiast from playing Jim Lovell in *Apollo 13*. His cinematic voyage whet his appetite to bring the Apollo story to TV.

It was anything but one small step for filmkind. The astronauts and their families only began the list of characters, which rivalled that of a Russian novel. Sets were needed for everything from the ill-fated Apollo 1 command module to Frank Borman's living room circa 1968. HBO anted up $65 million, making *From the Earth to the Moon* the most expensive miniseries ever made. My role shaped up as all-around Apollo consultant. I reviewed scripts and fielded questions like what kind of cars the astronauts drove (Corvettes were plentiful) and what kind of music they took on missions (often country-western). After filming began early last year there was the occasional urgent phone call: "They're about to shoot the scene of Al Worden alone in lunar orbit. Should he be wearing his spacesuit or not?" (No, like most command module pilots he had removed it after his crewmates landed on the moon and there was no longer the possibility of an emergency rendezvous.)

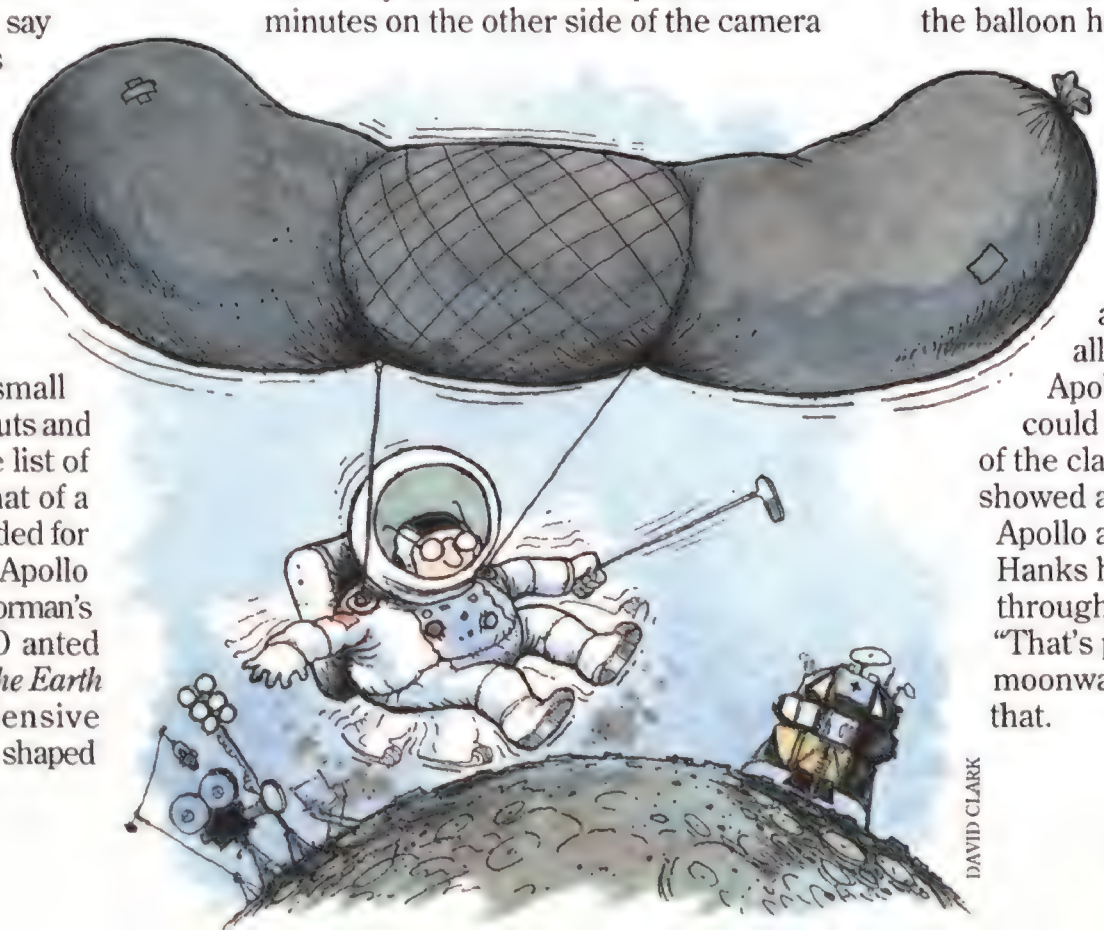
In April 1997 Hanks was directing the series opener at Disney Studios in Orlando, Florida. Scattered across the stage were replicas of Mercury, Gemini, and Apollo spacecraft. Across the hall was a re-creation of mission control so complete it might have fooled an Apollo flight director. In the costume department, spacesuits hung next to Ban-Lon sports shirts. The props department had cooked up everything from a replica of the "zip gun" Ed White used to maneuver on his Gemini spacewalk to an astronaut corps lapel pin. For me, witnessing the filming was like being a stowaway in orbit. I even spent a few minutes on the other side of the camera for a cameo as the host of "Meet the Press." My immortal line: "Miss Hedges, a follow-up?"

But the high point of my involvement came last October, during the filming of the lunar surface sequences in Tustin. Hanks was concerned about re-creating the moonwalkers' buoyant gait without resorting to hackneyed slow-motion photography. The solution: 50-foot-long helium balloons attached to the actors' spacesuits by steel cables (the balloons and cables were later removed from the image by computer). The effect was remarkable, not only to the eye but on my camcorder footage. "Don't show that to anybody," said one of the crew. "They'll think NASA faked it the first time."

Before my virtual lunar stay ended I had a chance to try moonwalking myself. After donning balloon-like longjohns (to give the suit a pressurized look) I was helped into the suit, boots, gloves, helmet, and backpack. I made my way to the edge of the set, where I was attached to one of the mammoth balloons. Feeling a bit too light on my feet, I asked for more ballast (weighted cushions in the spacesuit pockets). Then I started to try what I'd watched the stunt men do all week.

It was much harder than I expected—the balloon had a mind of its own and tended to steer me rather than the other way around. After a half-hour, I was exhausted—and had gained a new respect for stuntmen. Still, I could jump four feet effortlessly and land like a feather. And all those years of watching Apollo footage finally paid off: I could do a pretty mean rendition of the classic lunar lope. When I showed a videotape of my walk to Apollo astronaut Dave Scott, whom Hanks had enlisted to be on the set throughout production, he said, "That's pretty good." From a real moonwalker, I'll happily settle for that.

—Andrew Chaikin



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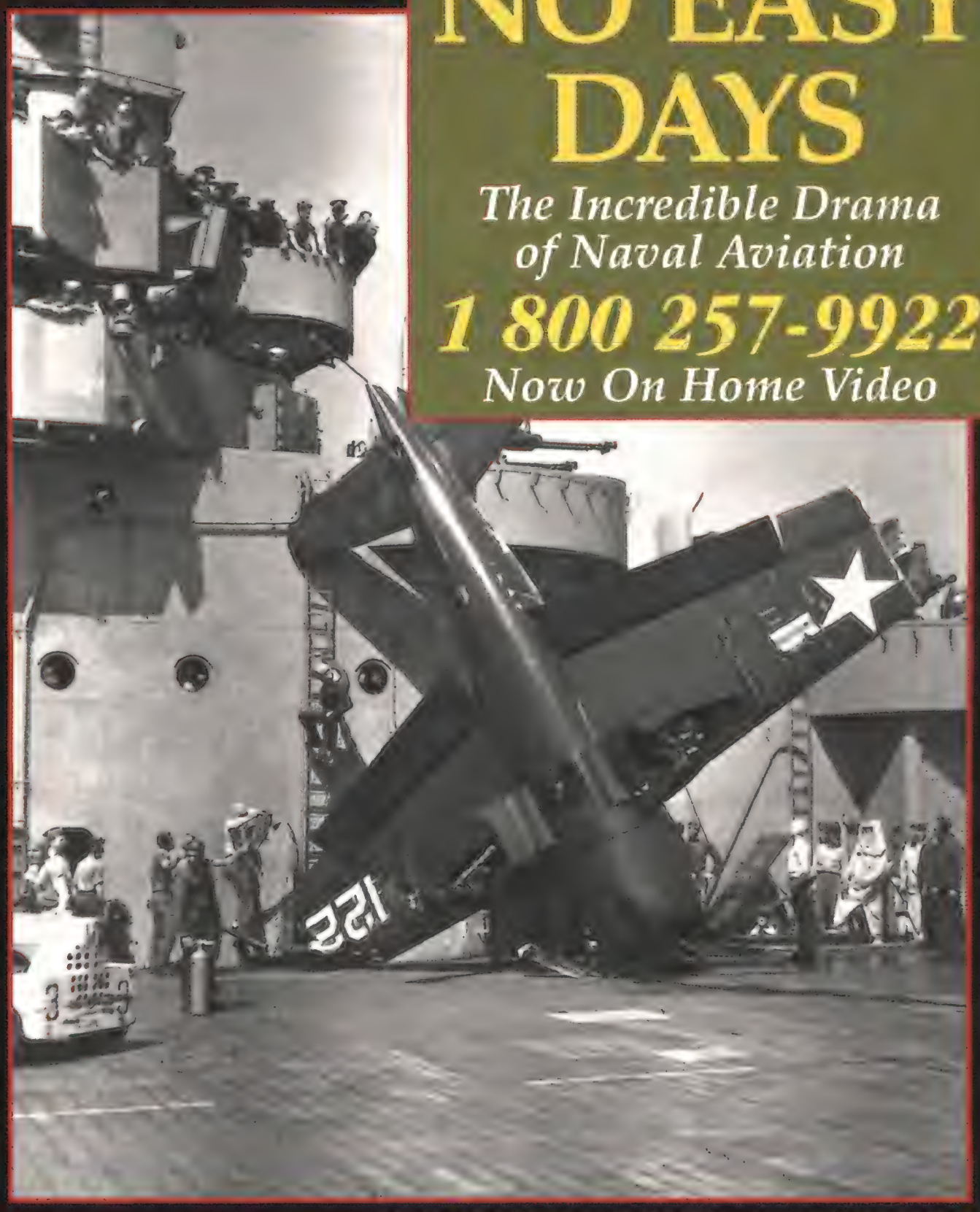

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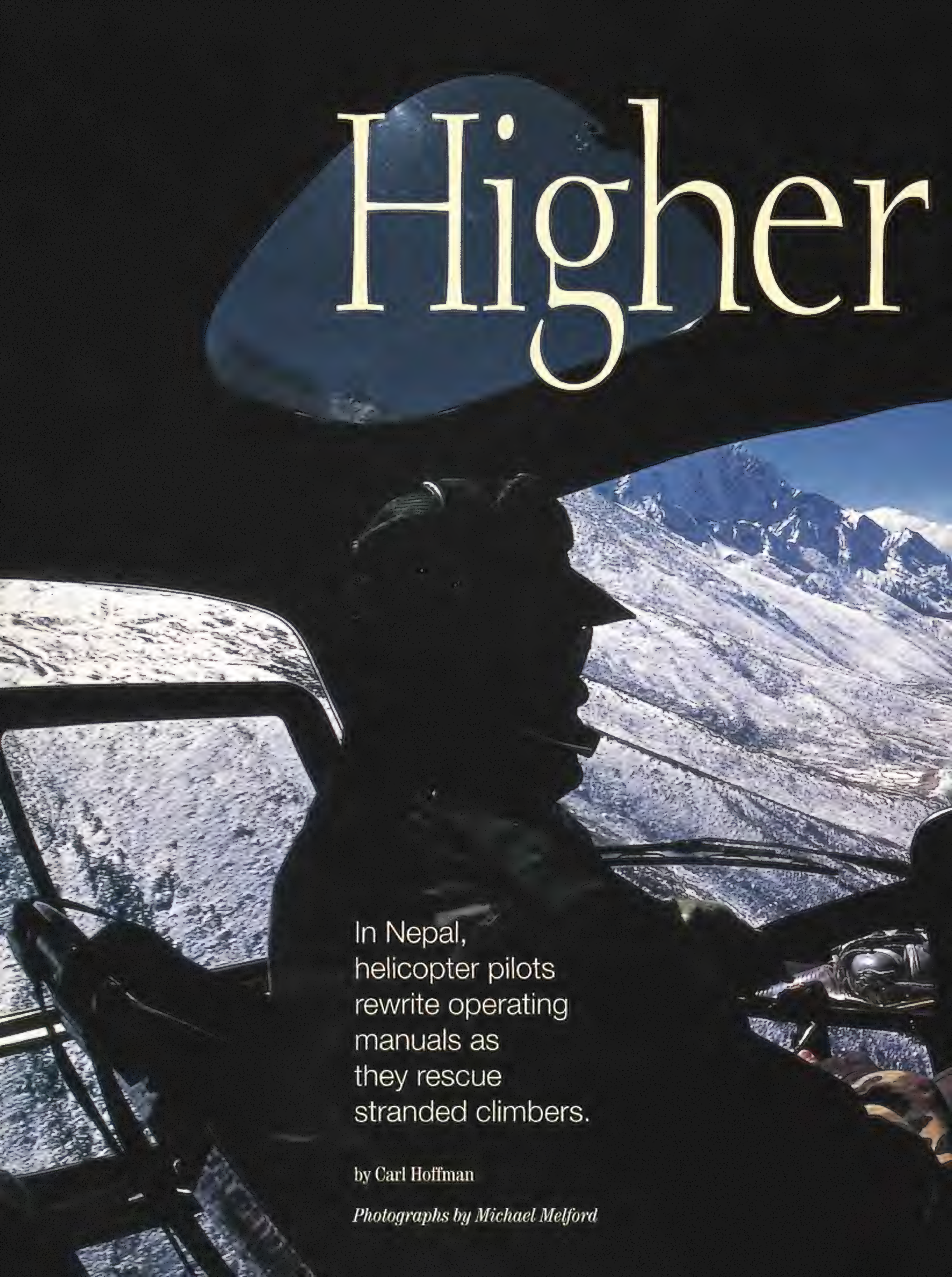

In Nepal, helicopter pilots rewrite operating manuals as they rescue stranded climbers.

by Carl Hoffman

Photographs by Michael Melford

Calling

Nepalese army helicopter pilots enjoy spectacular views while flying in some of the most challenging conditions in the world.

"If you are nervous flying in the mountains you will never make it," says Madan Khatri Chhetri. "You cannot be scared of anything."

From the cockpit of his helicopter, Madan gazes into the acrid yellow haze of a Katmandu afternoon. Smoke rises from countless fires smoldering in the brown valley, and at 500 feet above Nepal's Tribhuvan International Airport, the air feels balmy and thick. The controls rest easily in his hand. About a hundred miles to the northeast, the jagged peaks of Everest, Lhotse, Makalu, and Cho Oyu pierce the jetstream. White with snow and glowing irresistibly in the afternoon sun, they have drawn 25,000 climbers, trekkers, and thrill-seekers this November alone. In the back of Madan's olive-green Eurocopter AS 350B2 Ecureuil are two of them, best friends on the vacation of a lifetime: climbing in the shadow of Everest. One is sobbing; the other is dead.

A jet lands, Madan is cleared to cross the runway, and the helicopter beats slowly toward its hangar where Deepok Gurung, the head of the Nepal Hanuman Trekking Agency, is waiting for his dead client. He will make sure that the body—a man who died on a trip the trekking company arranged—is shipped back to Germany. Madan heads home, his workday finished.

At 44, Madan is a lieutenant colonel in the Royal Nepalese Army and the commander of its rotary wing. He is six-foot-two, with almond-shaped eyes that remind me of those on ancient Hindu carvings throughout the Katmandu valley. A thin gold loop runs through the upper curve of his left ear. Every time he flies, he touches a tiny bas-relief shrine to the Hindu god Vishnu. Madan started flying helicopters in 1979. Now, he's racked up 8,500 hours in the Himalayas, where he and a handful of current and former Nepalese army pilots have acquired more high-altitude helicopter experience than anyone else, anywhere.

Nepal is home to the highest mountains in the world, where eight peaks reach over 28,000 feet and hundreds of others soar over 20,000 feet. (The Rockies top out around 14,400 feet and Mount McKinley, the tallest in North America, is 20,320.) You can stare at these hauntingly majestic mountains for hours, like you can at fire or ocean waves. They are also at about the same latitude as Miami, so you can put on a T-shirt and trek into their foothills even in the late fall. In 1996 the mountains attracted nearly 400,000 tourists to Nepal—its main source of hard currency. With an ambitious advertising campaign, Nepal hopes to lure 100,000 more visitors this year.

But the mountains are also killers. At 17,000 feet there is only half the oxygen there is at sea level; atop Everest, at 29,028 feet, there is one-third. Climbers gasp for air and tire easily. As air pressure and density decrease with altitude, eyes, hands, and brains swell and the blood vessels in the brain can burst. Hypoxic, or oxygen-starved, people become reckless and irrational; they take off their gloves in bitter cold or walk off cliffs. It can happen to anyone, anytime, even Sherpas who were born and raised above 12,000 feet in the Solo Khumbu region near Everest.

Between January 1984 and June 1987, the only years for which statistics are available, the Royal Nepalese Army rescued 111 climbers and recovered 23 bodies. Since 1987, however, the number of tourists and climbers visiting Nepal has doubled, and today, in addition to the army, six private helicopter

GALEN ROWELL/MOUNTAIN LIGHT

Colonel Madan Khatri Chhetri (above) and his fellow pilots are busier than ever: The Nepalese government hopes to attract a half-million tourists to the Himalayas this year, and many will require rescue.

Fog, high altitude, punishing winds, and thin air that steals lift from rotors all test the skills of Nepalese army pilots and the robustness of their helicopters, whose insignia bear the trident of the Hindu god Vishnu (left).

operators engage in rescue operations in Nepal. Flying Alouettes, Bells, and Eurocopters, some christened with the blood of sacrificed animals and bearing Vishnu's trident, they set altitude records, extend the parameters in helicopter factory performance manuals, and rescue people almost daily at altitudes and in conditions most helicopter pilots never see in a lifetime. Just six weeks into the 1997 fall season, helicopters had pulled five bodies off Everest. Says Steve Webster, acting director of sales for Tiger Mountain, one of the largest trekking companies in Nepal, "In a country with terrain like this, if something happens and you can't walk, there's just no other way down."

The altitude is as harsh on helicopters as it is on people. And the frightening reality in Nepal is that the higher you go, the more likely you are to need a helicopter and the less likely you are to get one. Fuel pumps can't maintain enough pressure, and rotors have to churn faster and at higher pitch to grip the ever-thinning air. "The controls get sloppy and engine power response is slow," says Lieutenant Colonel N.S. Pun, "and when you need power, suddenly it's not there. You feel like you're balanced on the knife's edge."

In other parts of the world, pilots would not see that edge, or come close to reaching their helicopter's service ceiling. But Nepal's Himalayas are so far south that even at higher altitudes, the air is relatively warm. And the warmer the air, the less dense it is, which means that in Nepal, there is an unusually wide chasm between true altitude (the number of feet above sea level) and density altitude (true altitude adjusted for temperature and humidity).

Madan and his fellow pilots can't go by performance limitations on paper—their rescues lie outside the curve. "The manual for the Bell LongRanger says it cannot land or take off over 15,000 feet," says Colonel Gunga Man Lama. "The graph showing you how much power you need at certain altitudes stops at 15,000 feet. But I have landed and taken off many times at 16,500 feet [true altitude], which might have been 17,000 feet density altitude. Bell didn't believe me, but then I went to Texas and I brought a video that I took. So the guy ran into another room, played with the computer, and came out a few minutes later with a new graph. 'Here's your new graph to 20,000 feet,' he said, 'but we don't recommend it.' "

In Nepal, the pilot must make the difficult choice between following the manufacturer's recommendations and attempting a rescue. In May 1996, Madan chose to go for the rescue, and he set an unofficial record by landing a helicopter higher than any other pilot had.

He had just taken his second shot on the first hole of the Royal Nepal Golf Club when soldiers came running with urgent news: Toward the top of the world's highest mountain, an American climber was dying. Beck Weathers, a pathologist from Dallas, Texas, had reached the mountain's summit the previous day on a commercially guided climb and then been caught in

a sudden, ferocious storm that killed eight people. So frozen that one hand and part of another would later have to be amputated, Weathers was too badly injured to descend the Khumbu icefall and far too high, it was thought, to be rescued by helicopter.

Weathers' wife, who was in Dallas, pressured the American Embassy in Katmandu to hound the Nepalese army to attempt a helicopter rescue. The army balked. Of its eight helicopters, only one, the B2, had a service ceiling even close to the altitude where Weathers was. And of the four army pilots cleared to fly and land without a helipad at over 12,000 feet, three refused. "Everyone said the aircraft can't go there, that it was too high," says Madan. "But the embassy pushed too much and I thought, *Why not try?*"

By 8:30 that morning, Madan and his copilot were headed north up the Khumbu Valley. At the 12,000-foot-high Sherpa village of Namche Bazaar, they dropped their first cache of fuel and, airborne again, started breathing bottled oxygen. Caching fuel is a necessity when operating helicopters at these altitudes. Fuel is carried in portable containers and left at an intermediate staging area, allowing the pilot to carry as little fuel—and consequently, weight—as possible while he performs his rescue. Afterward, the pilot returns to his cache and refuels for the flight home.

The valley, rising quickly to the Everest base camp at 17,500 feet, is narrow and buffeted by high winds. "I decided to climb the ridge," says Madan, "and then go down the valley, because going up it, there is no place to turn around and if I can't get power it will be suicide." With eyes glued to the booster pumps supplying fuel to the engine, Madan climbed to 22,000 feet, 2,000 feet over the B2's ceiling. The helicopter handled surprisingly well. Heading down the valley with a strong tailwind, he saw no signal at Camp 1 or Camp 2. "I was not optimistic," he says. He circled four times and was just about to leave when he spotted people dragging a body and frantically waving their arms. "Many times you fly to evacuate someone and they start running when they see you and then you know it's not that serious, and you don't want to put yourself in danger. But those guys were really in trouble," he says. Madan flew closer, hit a downdraft, and plunged 2,000 feet in seconds. Too much weight, he decided. He returned to base camp and emptied the helicopter: his copilot, his extra bottles of oxygen, and all of his containerized fuel. He carried only 10 minutes' worth and a 10-minute reserve in his tanks.

Madan returned to the scene lighter but found the air still too thin to allow him to hover. The temperature was 15 degrees Fahrenheit and the helicopter was unheated. He had no jacket, no boots, no gloves or hat. Unacclimatized, had he been unable to leave the scene,

Careful maintenance keeps a French-made Alouette (left), ready to answer the dispatcher's call (below, right). Fuel canisters, like these beneath a Eurocopter Ecureuil (above), are jettisoned at intermediate landing sites—such caches allow pilots to reach the highest altitudes at the lowest weight. After the rescue, the stored fuel is the ticket home.

he would have died quickly. "The snow was fresh and full of big crevasses, I couldn't hover and I only had 20 minutes of fuel," he recounts. "I made two or three passes, checked my engine parameters, and came in very close to see if the fresh snow would blow." Madan was worried because such deep snow can spray upwards, white-out the pilot's view, get sucked into the engines, and stall the turbines. "I said, *Okay, I can land, but takeoff will be difficult.* I was at the highest power limit of my helicopter and if my rotor lost even a few rpms I'd be in trouble. The last time I'd flown to base camp I hadn't even been able to take off with one person. So I said, *Now God, you make it possible for me.* I just flew down right on the edge of the crevasse and tried to be as light on the skids as possible. If I kept it steady the snow would grab the skids, so I kept moving slightly back and forth, but I couldn't talk to them because I couldn't take my hands off the controls. They said 'Two!' I lifted one finger, indicating one. They put someone in, and I simply slid on the snow and dived down the mountain."

Moments later at base camp Madan found out that it wasn't Weathers at all in his helicopter, but a Taiwanese climber named Makalu Gao. "You can't imagine it," says Madan, "I had just seven minutes of fuel left. I went up again and got Beck; he was so excited when he got in the helicopter he started grabbing me. I was afraid he would make me crash. He was big and swollen and I almost didn't get off the ground." At base camp Madan picked up Gao and blasted straight to Namche while his low-fuel light flashed. He had just completed the highest known helicopter landing and rescue in history. Twice. Almost three thousand feet above the official service ceiling of his helicopter.

When Deepok Gurung of the Nepal Hanuman Trekking Agency got word that a 34-year-old German client had dropped dead on a glacier at 17,300 feet, he phoned the man's pregnant wife back in Germany, who refused to believe that her husband—an experienced amateur climber who was healthy when he headed out with eight buddies 10 days ago—could be dead. There had to be a mistake, and no, since it couldn't be him, she would not guarantee the cost of his evacuation. Gurung had to put up about $2,000, a fortune ten times the average Nepalese yearly income, and hope for the best.

The Nepalese army's operations center wasn't exactly springing into action to help Gurung out. There were eight helicopters sitting in its hangars, the duty officer was leaning back in his chair, and the room was filled with men in green uniforms waiting for their orders to fetch him tea or trim the grass or open his doors. But try as he might, Gurung couldn't seem to find a helicopter to get the body, and he'd already been at it for five hours. Gurung, alternately working the telephone and sitting patiently, wasn't about to give up, though. He had been to army headquarters and the German Embassy, and the embassy had written the requisite letter asking the Nepalese to fetch their national, all to no avail. Gurung even had a very thick envelope of U.S. dollars in his pocket to pay the $750-an-hour army charter rate. But a dead body isn't much of a priority in Nepal. Especially when it is frozen solid near the limit of most helicopters' range. "We have to wait and talk to Madan K.C.," said Gurung. "He's been to the States and we hope, well, maybe he'll understand."

The army, of course, isn't supposed to be first and foremost a rescue agency. Squeezed between China and India, Nepal has reason enough to feel anxious about its borders. But practically speaking, its eight helicopters—two Aerospatiale Super Pumas (used solely for carrying VIPs), three Aerospatiale Alouettes (which can't fly much above 12,000 feet), two Bell LongRangers, one Eurocopter AS 350B2 Ecureuil (there used to be two, until Madan missed a landing at 17,500 feet, destroying both rotors), and a motley collection of small transport airplanes have

little to do. Until 1990 the country permitted no private helicopter operators. If you needed one, you called the army and paid market rates for their charter.

Its first wave of pilots, men like N.S. Pun, who left the army in 1993, and Lama, who are now either senior officers or operating in the burgeoning private sector, trained with the air forces of India, France, and Great Britain. Pun, for instance, attended Britain's prestigious Royal Military Academy Sandhurst and the Indian Air Force's fighter pilot school before learning to fly Alouettes in the Alps with the French Air Force, which then sent pilots to Nepal to help train the Nepalese. A few pilots, like Madan and Major Dawa Jangbo Sherpa, learned to fly helicopters at commercial flight schools in the United States.

Now, most Nepalese army helicopter pilots receive their initial training in Pakistan or India, then begin a long apprenticeship under Lama, Madan, Brigadier General Puspa Khatri Chhetri, or Colonel Kinsendra Shahi. They fly as copilots for 2,000 hours and are limited to prepared helipads under 12,000 feet. It takes another 4,000 hours and nine years as a commander under an instructor before pilots are cleared for higher altitudes. In the world's highest mountains, experience is everything. There are no navigational aids, no weather reports from one valley to the next, and few prepared helipads. It is a turbulent, fickle environment of high winds and violent downdrafts that grab a helicopter and won't let go.

"At those altitudes we are pushing every mission to the very limit and it's very difficult flying," says Lama, 47, with 10,000 hours, "so the pilot has to learn slowly."

He must learn how to make decisions during high-altitude rescues with little fuel in his tanks after dropping containerized caches. "You never know if you'll be able to find a helipad or the person or if the weather will cloud, and yet you have no endurance," says Sherpa. That's what happened to Lama at 18,000 feet near the Makalu base camp: He'd gone for a rescue but couldn't land and started running out of fuel. On the way back to his cache, clouds materialized. "We circled, waiting for a hole," he recalls. "When the low-fuel warning light came on, I started the stopwatch. I knew that to the south the mountains were lower, so we headed south. Three, four, five minutes went by and I was waiting for the engine to quit."

The residents of the village of Chhukung live at a height halfway to the typical cruising altitude of a commercial jetliner (above). Sometimes it's too late for a rescue: The body of a German climber (opposite) is about to be loaded into the cabin of a Eurocopter (left).

With five minutes of fuel left Lama saw a hole and dived for it. He burst beneath the clouds, barely missing a tree, and landed safely. His fuel cache was a one-and-a-half-day walk away. Luckily, he says, "The village shop had just gotten a new load of kerosene and so we put 120 liters in the helicopter and flew home."

The familiar Himalayan difference between true and density altitude brought on by the unusually warm temperatures at high altitude is a constant challenge. Says Pun: "When we get to Everest base camp at 17,500 feet, for instance, the temperature should be 22, but instead it is 33, so for my helicopter the altitude is much higher." Which is why Madan was 3,000 feet over his B2's 20,000-feet ceiling when he rescued Weathers at 19,100 feet, and why Lama hadn't been able to land at Makalu.

Over the years the Nepalese learn the wind pattern of every valley—how it rises in the morning and sinks in the afternoon. They learn to read the wind direction in high, treeless terrain by looking at Buddhist prayer flags and the direction the cows are headed (conventional wisdom among pilots is that cows always face into the wind). They learn which passes they can cross and which are too high, about flying in sudden squalls and landing in snow, and about where to cache fuel and precisely how long it takes to fly between the various points in the area, such as Namche and Everest Base Camp. They learn the terrain intimately enough to fly the way Lindbergh and Saint Exupéry did: by feel and memory and dead reckoning. Nepalese pilots fly without maps, since all flying is done in daylight, under visual flight rules. Pilots also learn how to calculate engine performance from all those variables, regardless of what the manufacturers say.

"Flying in the United States or Europe, that is flying by procedure," says Puspa Khatri Chhetri, Madan's boss and a veteran of 10,000 flying hours in helicopters. "Here you are at high altitudes with no weather reports and no airports. You are on your own, with only your experience and your faith."

In 1993 Pun convinced the army to let him retire and start Nepal's first commercial helicopter operation. Since then he has started five of the six private helicopter companies in Nepal, two of which fly only huge, 24-person, leased Russian Mi-17s with Russian crews on regularly scheduled routes between Katmandu and Lukla, which has an airstrip at 9,100 feet. Karnali Air Services, Pun's latest company, and Nepal Airways Helicopter Services are both headed by former army pilots. Although the private companies charge as much as $1,000 an hour and are frequently closed for business, trekking companies arranging rescues prefer using them when they are available. "The private companies are more responsive and less bureaucratic than the army," says Tiger Mountain Travel's Steve Webster.

But on the day Deepok Gurung was desperately searching for a helicopter, Dynasty Airways' one helicopter was grounded, as were Nepal Airways' three Mi-17s and one AS 350B. A second Nepal

Airways AS 350B was flying, but unlike the AS 350B2, it has a ceiling of only 15,600 feet and couldn't get to the dead German. Karnali Air Services' two Eurocopters were also out of action: One had missed a helipad and crashed, killing two passengers a few weeks before; the other lay in pieces on the flight line.

Even if their aircraft were in perfect working order, the private operators are beholden to no one and shy away from risky flights. Although unburdened by military bureaucracy, the private companies must get permission from a variety of government offices to fly an unscheduled route and land away from an airport, which is the case with every rescue flight. All the private companies refused to rescue Weathers. "The army tries harder," says Prakash Adihikary, chief executive of the Himalayan Rescue Association, a private organization that operates two medical clinics in the area and runs training sessions on altitude sickness for climbers. "The private companies are always worrying about their helicopters."

Indeed, the army may be a ponderous, archaic institution with a lot of squeaky wheels that need oiling, but at least national security concerns keep a helicopter ready to fly at all times. And although the army is a proud institution that often bristles at the pressure foreign embassies routinely exert to rescue their nationals, as an arm of a government dependent upon foreign tourism, it does have to respond to that pressure.

All of which is why Deepok Gurung has spent a long day hanging around the army's hangars. It was his only choice. And sure enough, when Gurung tracked him down near 6 p.m., Madan said he could make the flight. Sometime. Maybe tomorrow. Maybe the day after. It all depended on the general and permission from army headquarters. As for the general, well, it was the queen's birthday and he was drinking tea at the palace. Gurung, his dead

The beauty of the Himalayas can literally take your breath away. Many climbers overcome by altitude sickness or by the swollen tissues of pulmonary or cerebral edema have one chance left: helicopter rescue (below).

client, the client's wife back in Germany, and the German Embassy would all have to wait.

At 8 p.m. the call finally came in: Madan would be ready to fly tomorrow at 7 a.m.

By the time the morning fog lifts enough to fly, it's almost nine, nearly too late in the day to begin a mission. Madan is dressed in his usual high-altitude rig: green cotton flightsuit, slip-on black leather booties, and a maroon ascot. He touches the little shrine to Vishnu and fires up the AS 350B2, with copilot Major Promod Lama (no relation to Gunga Man Lama). In 10 minutes we're skimming over the green ridge of Nagarkot at 115 mph, climbing past 6,500 feet, headed east and parallel to the big mountains toward Lukla at 9,100 feet. There Madan will turn north and begin flying up the Khumbu toward Everest. He has no map and no weather report; he knows the route by heart. Below are steep, roadless, green terraced hills cut only by occasional footpaths snaking along steep ridges and tiny villages. Wisps of ground fog line the deep valleys, and the air, at this time of morning, is still.

Commissioned as a second lieutenant at 19, Madan served in the army signal corps and as a paratrooper and commando before an army DC-3 crashed into a power line in 1978, killing five Nepalese pilots. Twenty-four tested for the available positions; Madan scored highest and was off to flight school at Burnside Aviation in Tamiami, Florida. "I was very excited," he says. "I hadn't even driven a car." In 1994, after more than 15 years flying in Nepal, he traveled to France for type training on the B2. "One day the instructor in France said, 'I'll take you on a high-altitude mission,' " remembers Madan. "He said, 'We'll have to start at 6,000 feet and move progressively higher.' I said, 'Sir, every pilot in Nepal flies higher than that. Katmandu airport is 4,500 feet. Let me land at your highest elevation and we'll see what you think I need.' So I took him to 13,000 feet, made a pass, and then landed. 'Colonel,' he said, 'you don't need any training. Let's go eat breakfast!' "

By 9:00 a.m. we're doing 105 mph at 11,500 feet, just 300 feet over a mountain ridge that is the gateway into higher country. Updrafts make the helicopter bump along like a car on a dirt road. Madan always flies in the sun, if possible, to get extra lift from these updrafts. Rocky, snow-covered walls loom on the left—up narrow valleys Madan has to fly with the rotors as close as three feet to the sides of the canyons to give him room to turn around if necessary—while to the right a green world falls away in undulating foothills toward the Indian plains. Inside the helicopter the temperature is dropping; I start to feel lightheaded and breathless. At 12,000 feet Everest surges into view, a shimmering behemoth trailing a white streamer of blowing snow.

Madan averages 40 hours of flying a month, but in 1989 an earthquake struck the southern part of Nepal, and in one month he was in the air 256 hours. The most challenging rescue flights have less to do with altitude than with snow and frightened people who may have wandered from where they're supposed

to be, or are likely to stampede the helicopter, or can't shut the door once inside. In 1985, 36 New Zealanders trekking at 15,500 feet were hit by a storm that dropped as much as 10 feet of snow. Two weeks had passed and six had died of starvation and exposure by the time Madan found them. Worried about the snow depth, Madan tried to signal for them to stamp out a helipad, but they were starving and desperate and couldn't understand. With his copilot at the controls, Madan hung from the skids. But when the snow was already at his waist and he couldn't feel solid ground, he signalled to be pulled up. "The snow was just too deep," he says. Back in the helicopter, Madan flew to a village and bought a rope at the market, which he tied around the skids. Dangling the rope, they managed to pull the leader out even as people were "crazy and fighting each other to get on the helicopter," says Madan. After convincing the leader to go back to the group, get them under control, and stamp out a helipad, Madan rescued everyone in six flights.

At 9:30 Madan lands on a dirt airstrip at Syangboche. A few trekkers stop, and as yak bells clang, he unloads his fuel cache, 25 gallons of fuel in plastic jugs, then puts on his oxygen mask and takes off again. I have to stay behind; the body is supposed to be at the Island Peak base camp, 14 miles away, and I weigh too much.

The air is startlingly crisp. We are 12,300 feet high, having come directly from the lower levels of Katmandu, and I feel drunk and silly.

By 10:15 Madan comes clattering back down the mountain. Jammed between the front and rear seats on the floor of the helicopter lies the body, face down: A pair of new leather hiking boots; skin tight, blue Lycra climbing pants dusted with frost; a tattered blue plastic tarp and climbing rope wrapped around the torso. A pale, bruised elbow sticks out from a fold. We pull the stiff body out. Madan jumps back in and takes off to pick up the dead German's friend.

The evacuation, Madan says later, was difficult. Unable to find the body, he had to pick up one of the party's Sherpas, who showed him the German lying in the snow at 17,300 feet. The temperature was 27 degrees Fahrenheit, producing a density altitude of 19,000 feet, and there was a heavy tailwind. "The body was heavy and the helicopter was sluggish—I was at full power to get off the ground and there was little response," Madan says.

A few minutes later Madan returns with the dead man's partner. He is dazed, windburned, and sullen. We load his dead friend into the helicopter, and Madan takes off. "We were climbing, it was four in the afternoon, and he said, 'I don't feel well,' " the friend mutters. "That was it. There was nothing we could do."

Suddenly a radio call prompts us to divert toward Pahphlu, where a local woman is in labor and near death. A crowd surrounding a stretcher waits at the village's grassy airstrip, 8,000 feet high. We remove the body, which will have to be picked up later, along with the friend and me. Then we gingerly place the woman, under thick blankets and with an IV attached to her arm, into the back of the helicopter. Madan heads to Katmandu.

Two hours later, Madan comes back for us, and after a 30-minute ride, we land with a soft bump at Tribhuvan International Airport. The hangar, the mass of airplanes and helicopters, the hot air, so luxuriously humid and rich that you want to gulp it down like food, all seems a world away from the cold world of snow and thin air. The German breaks into big, chest-heaving sobs. It wasn't supposed to be like this. He climbs out over his friend and stands dumbly next to the helicopter in his shiny mountain gear, a costumed actor in a play that's suddenly gone awry. A soldier walks up bearing a small bronze bowl of water and a sprig of pine. Madan bows his head slightly, and the soldier flicks water on each one of us. "It is holy water," says Madan, shrugging his shoulders. "Now we are purified. In the mountains, whatever you have done, you must be calm and peaceful."

Fifty years ago, they worked around the clock to keep Berlin from starving. Now, in a year-long celebration, Berlin invites them back.

by Linda Shiner

HEROES WELCOME

It was a British idea. On June 25, 1948, Foreign Minister Ernest Bevin ordered his Chiefs of Staff to put together the largest force of transport aircraft possible to carry food to the civilian population of Berlin. The day before, Soviet occupation authorities had cut the supply of electricity to the Western half of the city and had stopped rail, road, and barge traffic from going in or coming out. Bevin organized an airlift, he told a U.S. diplomat, to boost the morale of the Berliners and show the Soviets what Western air power could do.

The U.S. Army had concluded months earlier that supplying Berlin by air would be impossible. At the end of the war, U.S. forces had been brought home faster than you can say "de-mobilize," and the commander of U.S. Air Forces in Europe at the time, Major General Curtis LeMay, had only about a hundred Douglas C-47s to carry men and cargo. In the tense weeks preceding the Soviet blockade, the U.S. military governor in Germany, General Lucius D. Clay, reappraised his situation but reached the same conclusion. "We can maintain our own people indefinitely," he cabled Washington on June 13, "but not the German people if rail transport is severed." Two weeks later as the blockade began, Clay cabled again: "Our people are calm and quiet. Personally, I have little fear of crisis affecting us. What I do fear [is that] such suffering [may be] brought upon Germans in Berlin as to drive us out to relieve their suffering."

Unlike the British Foreign Minister, Clay had witnessed the privations Berlin endured while its supply routes were open, and he understood the city's predicament. Clay knew that Berlin had been importing as much as 12,000 tons of supplies daily—that it needed 2,000 tons of food a day for the most meager subsistence—and he never dreamed of bringing it in by air. Instead, he repeatedly asked for, and was denied, permission "to force the issue" by sending an armed truck convoy across the hundred miles of Soviet-occupied Germany.

As the blockade began, Clay called on LeMay to supply the U.S. garrison, as he had done for a few days in April when the Soviets had interfered with military trains. He asked LeMay to fly 45 tons of food into Berlin. LeMay sent 80. And Clay decided to go for it. With the Royal Air Force already committed to throwing everything they had into an airlift—40 Dakotas (British C-47s), 35 Avro Yorks, and 26 Handley Page Hastings—Clay cabled the War Department on June 27: "it is urgent that we be given approximately 50 additional transport planes to arrive in Germany at the earliest practicable date." LeMay told Clay to get Douglas C-54 Skymasters, the biggest transport the Air Force had in any significant number. They could carry 10 tons each.

On June 28, 21 C-54s from the Panama Canal Zone and Alaska arrived at Rhein-Main Air Base. The following day 22 more flew in from Bergstrom Air Force Base in Texas and Hickam Field in Hawaii. Another 43 reported for duty in July. By October, the newly formed Military Air Transport Service had committed to the operation 300 of the approximately 400 C-54s left in military service; 19 more were sent to Great Falls Air Force Base in Montana to train pilots solely for the lift. The U.S. Navy pitched in with two squadrons and 24 R5Ds, the Navy C-54. No one, not even Bevin, thought airplanes could sustain the city for more than a few weeks; after that, it was hoped that diplomacy would open the land routes once more. No one would have predicted that the operation would see Berlin through the winter, that it would become an aerial conveyor belt in continuous motion from June 1948 to September 1949, delivering 5,500 tons of food, medicine, and coal a day.

For the youngest Berliners, who had known only war and its desolate aftermath, U.S. Air Force C-47s on goodwill missions were something to celebrate.

UPI/CORBIS-BETTMANN

Lockheed's C-5 Galaxy, today the biggest airlifter in the U.S. fleet, can carry 130 tons without breaking a sweat. When the Air Force sends a C-5 to an airshow, it goes with a placard noting that it would have taken only 17 C-5s to do the job of the aircraft that flew in the Berlin Airlift. On the other hand, the Air Force also points out, the total tonnage

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delivered to Sarajevo between 1992 and 1996—179,910 tons—is less than the amount delivered to Berlin in March 1949 alone. Despite the remarkable movements of men and machines that the Air Force accomplished in Vietnam and Desert Storm, after 50 years, Berlin is still the standard by which airlifts are measured.

"It was so constant," says Bill Voigt, who flew to Berlin 116 times between July and November. "If you don't think that sharpened your ability to fly—making all those precision landings." Voigt, a stocky 78-year-old with a gray crewcut, has 11,300 hours in military aircraft, 6,000 of them in C-54s.

Landings were tricky at Tempelhof, the airport in the U.S. zone of Berlin. Seven-story apartment buildings stood not far from the end of a 5,000-foot runway. "You'd come in at a pretty steep angle," says Voigt. "It's not a heck of a lot of space with a fully loaded airplane. And the surface [pierced steel planking] would slide with you. It was pretty hard on the brakes and tires.

"The regs tell you not to cut power till you're on the deck," Voigt continues. "But there's two ways to cook eggs. Everybody has his own technique. As soon as the apartment buildings disappeared from my peripheral vision, I pulled back to idle. Then I put power on to flare." Pilots flying the same approach two or three times a day, day after day, for three months had a lot of chances to refine their techniques.

Besides all the hours flying military aircraft, Voigt has thousands more restoring them. He works as a volunteer on

airplanes rescued by the Air Mobility Command Museum at Dover Air Force Base in Delaware—among them, one of the C-54s he flew in the lift. We are sitting in the museum's 20,000-square-foot exhibition hall, admiring a past project: a grandly restored Douglas C-47—one of the hundred that hauled groceries into Berlin, two and a half tons at a time, until the bigger, four-engine C-54s took over.

In the presence of this icon, Voigt confesses that he wanted to fly fighters. Instead, after basic, he was retained as a flight instructor, "finally wiggled out of it," and was sent to Air Transport Command. "Ended up flying Gooney Birds," says Voigt. "Big deal."

But in 1948, flying transports became a very big deal. The mission facing the new Air Force—to keep Berlin from the clutches of the Russians—couldn't be done with fighters and bombers. Not that the Air Force didn't try. In early July the service experimented with coal delivery by stuffing bags of it in the bomb bays of a couple of B-29s, which released their stores at low level. When the coal hit the ground, it disintegrated. And after the dust settled—everywhere—the Air Force faced the dirty, time-consuming, labor-intensive reality, and coal was instead loaded on C-54s, bag by 100-pound bag. It became the airlift's chief commodity; a million and a half tons were delivered by the time the lift ended.

"I never made a trip to Berlin that I didn't carry coal," says Voigt. "We were dirty. The planes were dirty." When C-54s returned to the States for their 1,000-hour overhauls, they

COURTESY JAMES SPATAFORA

were sometimes hundreds of pounds heavier because of the coal dust that had settled in their innards. In 1989, when curator Jim Leech and volunteers at the Air Mobility Command Museum started working on Voigt's old C-54, they found coal dust still clinging to the bulkheads.

The Military Air Transport Service hadn't planned for a situation in which coal would be its primary cargo and hadn't anticipated the requirements of a strategic airlift in general. MATS C-47 and C-54 transports were derived from passenger aircraft, awkward to load and unload. The first freighter designed as such, Fairchild's twin-engine C-82 Packet, was a boxcar hung between two booms with rear clamshell doors for straight-in loading at ground level, but it had less capacity and less power than the C-54.

The most daunting problem facing MATS, however, was not how to load airplanes or even how to keep them in flying condition, though the maintenance tasks for the operation were Herculean. It was how to get all those airplanes

In the 15 months of the lift, only 24 aircraft were lost, including this C-54, which skidded off the Tempelhof runway. German workers made commemorative plaques (opposite) from the crashed airplanes and gave them to pilots and mechanics. Even Germany's winter weather didn't stop the C-54s from making deliveries (opposite, top).

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into two—later three—airports. "You had an airplane landing or taking off every 90 seconds," says Michael Leister, the director of the AMC museum.

MATS solved the problem with Ground Controlled Approach, a precision landing aid using a radar operator to tell the pilot his position relative to the approach path. The operator would pick up an aircraft on his scope from about two miles out and talk the pilot down to a landing. "GCA was very reassuring," says Harold Watson, who was called back to the Air Force from his job at TWA and made about 200 flights in the lift. "Berlin is what made it acceptable to civilian pilots. The operator was continuously talking and very calm. He'd say for example: 'You're 50 feet below the glideslope, coming up slow' or 'two degrees left.' If we didn't correct, he'd remind us. It was life-saving to us."

Though the accident rate was low—31 U.S. fatalities in 189,963 flights—the congested airspace over Berlin dramatized the need for ever larger transports to lift the same loads in ever fewer trips. The airlift helped fuel a "bigger is better" trend as well as a push for mission-specific airlifters—both apparent in the heavy-lift C-5 and the short takeoff-capable McDonnell Douglas C-17A flying today.

"We have policies today that are directly related to the Berlin airlift," says Tom Cossaboom, the historian of the Air Mobility Command. "It's more than Air Force policy. Airlift is today an instrument of national policy."

The success in Berlin, he continues, also had a tremendous impact on the course of U.S. foreign relations. "Remember there was a Republican-controlled Senate at the time," he points out, "and Republicans were historically reluctant to get involved in long-term foreign alliances. The airlift influenced the decision to stay in Europe." Not only did it make the U.S. Congress a more willing participant in NATO, says Cossaboom, "it did a lot to push European governments into the alliance."

It instantly changed the attitudes of the people involved in it. Some of the pilots who flew to Berlin had bombed the city just a few years earlier, and most flying the lift still considered Germans the enemy. Earl Moore, a retired Navy commander, remembers the animosity he and his colleagues felt toward the Germans at first. "I didn't give a damn whether they lived or died," he says, "until I saw them."

Werner Hauer, a communications specialist living in New Jersey, was a young man in Berlin during the lift and says he witnessed the conversions. "In those days [before the airlift], no troops were friendly," he says. "Not Russians, not Americans or British either. There was a very hostile feeling. It wasn't over. They terrorized us as badly as Hitler. It changed through the airlift. We knew we were in the same camp." He adds: "Until the '60s."

The airlift's effect on the Soviets was no less significant. "Oh, it stands head and shoulders above anything else in embarrassing the Russians," Cossaboom says. The Russians were so badly outmaneuvered in terms of world opinion that one has to wonder what they had hoped to gain from blockading Berlin. Until a few years ago all any Western historian could do was wonder. Nearly all cold war interpretations of Russian motives followed the lead of George Kennan, U.S. ambassador to the Soviet Union in 1952 and a towering figure in Russian studies. Kennan argued convincingly that expansionism, the inescapable product of Soviet history and ideology, drove the country's foreign policy. Now with increased access to Russian and East German archives, some scholars propose that the Soviets had not hardened their policy of expansionism in Germany by the time of the blockade. Recent studies maintain that the Soviets wanted to negotiate, an opinion held at the time by General Clay, and that the blockade was, as Soviet historians have claimed, a response to the Western introduction of a separate currency in their zones and other moves to cut Germany in half. Whatever the motivation, the Soviet blockade was clumsy, cruel, and, thanks to the airlift, mortifyingly ineffective.

Although four powers—Soviets, Americans, British, and French—occupied four zones of Germany and its capital city, only the Soviets had unlimited access to Berlin. The others relied on a 1945 agreement stipulating that Western aircraft would enter and depart the city through three air corridors, each 20 miles wide. The corridors channeled traffic between Berlin and three urban centers in the Western zones: Hamburg, Hannover, and Frankfurt. During the lift, the Americans flew into Berlin through the southern corridor, while the British—and Americans flying coal from British air bases—used the shorter, northern corridor. All outbound flights used the central corridor. Airplanes took off every three minutes, 24 hours a day. Yak fighters buzzed a few from time to time, but for the most part the Soviets did not interfere with their movement.

"When the weather was good, you could see as many as six airplanes in front of you," says Ken Herman, a past president of the Berlin Airlift Veterans Association. Herman was a 25-year-old pilot testing Boeing C-97s for the Air Force when he was called to Berlin in August 1948. He flew 190 missions, most of them carrying coal from Fassberg, a British base near Hannover where 45 C-54s had been staged.

"Once you entered the corridor, there was no turning back. You went to Berlin," says Herman. And if a pilot missed his approach in Berlin, there was no second try. He had to take his cargo back where he came from.

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"That was Tunner," says Gail Halvorsen, a retired Air Force colonel who made 126 flights to Berlin. "You couldn't believe the number of lives he saved."

General William Tunner is renowned among airlifters. He had run the Hump, the legendary World War II supply route over the Himalayas into China, and was brought to Wiesbaden, Germany, in August 1948 to direct Operation Vittles, the Air Force designation for the Berlin airlift. The ultimate efficiency expert, Tunner standardized operations and frowned on heroics. "A successful airlift," he wrote in his memoirs, "is about as glamorous as drops of water on a stone." And as steady. Tunner ordered the pilots to maintain the three-minute interval in the corridors, and outlawed stacking over Berlin. Pilots had one shot at delivering cargo.

"We hated like the devil to take it home," says Halvorsen. "We'd sometimes sneak a little bit."

If the minimums for Tempelhof required half-mile visibility and a ceiling of 400 feet, for example, pilots would sometimes descend to 350 or even 300 feet before they broke out of the cloud. But they wouldn't let on to the controllers in the tower that they were exceeding the minimums.

"You'd hear the last pilot to let down in front of you answer an inquiry from the tower that the ceiling was at 500 feet," says Bill Voigt. "And you'd glance down at the altimeter—you saw 500 feet and you can't see out to the wingtips. So you drop down another hundred feet or so.

"It wasn't disgraceful to take the load back," he adds, "but you just didn't want to do it."

The Air Force built another runway at Tempelhof in October, but for the first three months there was only one way in regardless of weather. "We could operate our -54s in 35 mph crosswinds," says Voigt. "If you're drifting, you drop a wing into it, land on one wheel. We were good."

At an airlift veterans' reunion last October, old-timers remembered the group of young pilots who had a wild time before Tunner showed up. "You'd take off after your buddies, scream around the circuit [to Berlin and back], and try to be there when they got back so you could ask what took 'em so long," Halvorsen recalled, shaking his head. "Stupid."

"People really did that?" a listener asked.

"Oh, yeah," said Halvorsen, adding sheepishly, "I did that. Once."

Well, he was young. And, as Berliners will tell you, he more than made up for his hijinks. They may not know the name Halvorsen, but every one of them can tell you the story of the Berlin candy bomber.

Halvorsen was a fresh-faced beanpole from Utah when he volunteered for the airlift. One day he spotted a group of kids watching the airplanes land at Tempelhof and, after a brief chat, got the idea to drop them his candy rations. He did it secretly at first, fearing he'd get in trouble, his copilot and flight mechanic adding their chocolate bars and chewing gum to his, tying their handkerchiefs to the small bundles as parachutes, and *bombs away!* on final approach. Somehow a reporter with the *Frankfurter Zeitung* got wind of it—almost bonked on the head with a candy bar, the story goes—and Halvorsen came back to his bunk one night to find it piled high with handkerchiefs and chocolate bars. The other airmen on the base had read the paper. The Air Force loved it, and sent him home for a weekend to do a couple of national TV shows. The candy drops became Operation Little Vittles, complete with corporate backing and its own statistics. Chocolate and handkerchiefs came into Rhein-Main from all over the United States. The town of Chicopee, Massachusetts, which set itself up as the U.S. headquarters for candy bombing, alone shipped to Germany 2,000 sheets for parachutes, 3,000 handkerchiefs, and 18 tons of candy.

This year Halvorsen, 78, is returning to Berlin to drop candy from *The Spirit of Freedom*, a C-54, restored by the Berlin Airlift Historical Foundation, that carries airlift memorabilia and photographs instead of coal or flour. One of Berlin's favorite heroes, Halvorsen will be a popular figure at the events commemorating the airlift's 50th anniversary. At the 40th celebration in Berlin, he signed autographs for hours from the cockpit of a parked C-54, frequently on tattered pieces of cloth handed him by middle-aged Berliners who had been lucky enough to catch them many years before.

Cumbersome unloading operations (opposite) dramatized the need for transports designed specifically as cargo carriers. To speed the turnaround, chow wagons were parked near the unloading depot (above)so that pilots wouldn't have to leave their aircraft for food and coffee. Gail Halvorsen delighted the children of Berlin by dropping treats on final approach.

NASM

In Halvorsen's estimation, the real heroes of the airlift were the mechanics. "They weren't in covered facilities," he says. "The airplanes were out in the weather. Sometimes it got so cold, they were freezing their fingers to the head bolts of the cylinders."

"We had an hour and forty minutes for everything—refueling, reloading, preflight inspection, reservice, and any maintenance that had to be done." says James Spatafora, 69, who left his job in a Brooklyn necktie factory when he was 17 to join the Air Force. Spatafora had been trained as a hydraulics specialist on P-51 fighters and says he "really had to crack the books" when he got to Rhein-Main and started working on C-54s. "But there was no such thing as staying in your specialty," he recalls. "I helped props people change props, instruments people, electricians, towed airplanes. I loved every minute of it. Nothing heroic about it. Just ordinary people living in extraordinary times."

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Katharin Brandt lived in Friedenau during the blockade, in what was once the American zone. She lives in the same district today and recalls that in the first weeks of the blockade, her greatest fear was that the Americans would abandon the city to the Russians. "I remember that in the night when I heard trucks moving in the streets, I thought—we all thought—*Oh, now maybe the Western allies are moving out of Berlin*," she says. Brandt was a secretary in the U.S. liaison office of the Kommandatura, the four-power military administration that governed the city. The liaison offices were located in the Russian sector—in the same building as the city's elected government—and Brandt remembers the violence that terrorized Berliners as the city divided.

"There were riots in the streets," she says. "When Parliament was in session, the Russians mobilized workers to go out in the streets, brought in by trucks. They tried to get into the Stadthaus and disturb the ses-

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The Royal Air Force delivered salt, among other basics, in Sunderland flying boats. A major partner in the airlift, the RAF flew 87,841 flights delivering almost 550,000 tons.

sion of the Parliament—they have done that several times before the blockade started."

Waltraud Kuck doesn't remember fear, only hunger. She was an 18-year-old girl in the "working brigade" that built Tegel Airport in the French zone. She earned 15 marks a week and one hot meal a day, which was her only meal. The only time she could forget her hunger, she says, was when she was dancing, and she went out nearly every night. "Even today, I'm not able to throw a bit of bread away," says Kuck.

"The majority of the people there were clearing the ground with shovels. And I was lucky. I was responsible for preparation work, for measurements and things like that," Kuck says through a translator. "The other young girls who really had to work hard—they had blisters on their hands.

"On the working brigade, the atmosphere was great," she continues. "Much better than today. Everybody was helping each other. We had the feeling that things would improve."

She also remembers that her father quit smoking because on the black market "with cigarettes you could pay for everything," that some of the young boys who unloaded the aircraft carried sacks of flour that weighed more than they did, and that whenever she and her friends heard an airplane overhead, they would call to it, "Airplane! Please drop some chocolate!"

"Those who lived in this time have a knowledge about it and they will never forget. But it's up to people like me to bring this subject into the city," says Heinz-Gerd Reese, a large, friendly administrator in the city government.

Reese is also the director of Berlin's Airlift Foundation, which the city founded in 1959 to give assistance to the families of the 78 British and American men who died in the airlift. Part of his job as director has been to oversee the stipends and scholarships that are still paid to some of the widows and children. But Reese, who has a zest for public relations, has also been working since 1992 in anticipation of this year's million-dollar celebration. In the elegant Berlin Rathaus, Reese describes his plans.

"I want to shake this city," he says. Berliners who buy tickets to an open air concert in the city this month are making a donation to CARE Germany. The ticket itself is a return address label—to be filled out like a raffle ticket—that will be affixed to a package from CARE (Cooperative for Assistance and Relief Everywhere). "All the CARE parcels will be flown out of Berlin into somewhere where people need it," explains Reese. "Every parcel gets a name so the receiver knows from whom it comes. We want to show that the Berliners have not forgotten what was done for them, and we reverse the airlift to other parts of the world."

This June 27 and 28, the foundation will sponsor an open house at Tempelhof Airport, which will coincide with the opening of the Allied Museum located near the former U.S. military headquarters, and will donate 30 flights around Berlin in a C-54—"a candy bomber," says Reese.

UPI/CORBIS-BETTMANN

Reese has asked all the Berlin hotels to place on their guests' pillows little chocolate airplanes. He has arranged a parade of flying boats on the Havel River, where British Sunderlands delivered salt, an international conference of scholars and airlift contemporaries, airshows, high school band competitions, and fireworks displays. For 11 months, "we'll cook it," says Reese, "until the last event on the 12th of May 1999, we'll have

a military concert in the Olympic Stadium to honor the veterans. They will march in at the gate and then to their seats. And I hope there will be 60,000 Berliners in the Olympic Stadium."

Katharin Brandt and Waltraud Kuck say they will attend. And Werner Hauer is planning to fly in from New Jersey. Because Berliners are proud of living in what was the capital of the cold war and memorialize the airlift as a defining moment—they quote political speeches from the time in the same way Americans remember "Give me liberty or give me death"—Reese may just fill the stadium. Will the younger generation be represented? A translator in her 20s said yes, she thought she'd go; the people of her generation want to remember the airlift because it is something good. "They are tired of feeling the need to explain Germany's history in the second world war," she said. "It's nice to have something for a change that is positive and can make them feel some pride in being German."

In a small green park near Tempelhof Airport is a concrete

TOM SHINER

sculpture, a heavy 1950s design intended to represent the flight paths of three aircraft—symbolic of the British, French, and American allies—in a steep climb. The paths emerge from a concrete slab and form three prongs; Berliners call the sculpture "the hunger claw." The memorial is dedicated to those who died during the airlift. Their names are inscribed on its base.

On an afternoon last September, a friend and I visited the memorial. Three boys lounged on the lawn in front of it, backpacks and a soccer ball in the grass nearby. My friend asked them in German what the memorial was and they all answered "Die Luftbrücke," the air bridge. Yes, but what was it, my friend went on, what did it mean? Airplanes were flown into Berlin, the three spoke at once. And who was flying the airplanes? we asked. The Americans, the French, and the Russians, one said after a brief consultation, and another directed us to the sign that had been placed there for pesky tourists like us.

Poor old Bevin probably rolled over in his grave and the history teachers in Berlin wouldn't be overjoyed either. I wonder if the veterans who will fly to Berlin again this year would mind the confusion over who exactly the good guys were. There are some who would set those youngsters straight. But there are more who would, after all these years, welcome the Russians aboard. At least three Berliners already have.

Berlin was bombed to rubble in 1945 (opposite) by some of the same pilots who three years later flew C-54s to save it (below). Berliners remember the airlift with a monument near Tempelhof (above) and this year's 50th anniversary celebration.

NASM

THE WALL STREET DECADE

Why it began, how it ended, and the financial analysts at the center of the action.

by Bruce D. Berkowitz

Illustrations by David Povilaitis

It's hard to pin down exactly when it began, but future historians are likely to mark March 23, 1998, as the day it ended. On that Monday, when the Department of Justice filed suit to block Lockheed Martin's acquisition of Northrop Grumman, the aerospace industry's "Wall Street Decade" came to a close. Until Attorney General Janet Reno and Secretary of Defense William Cohen stepped up to oppose the $12 billion deal, the U.S. government had been playing a supportive role in a seemingly unending consolidation of the largest aerospace firms.

History may mark the beginning of aerospace merger mania as early as September 1985, when Allied Corporation, originally a chemical and fibers manufacturer, and the Signal Companies formed AlliedSignal, in the process melding their aerospace firms: Bendix electronics and Garrett turbine aircraft engines. What really accelerated the process, however, was the end of the cold war. In 1985, when the Soviet Union was still considered a viable threat, the defense department spent $81 billion on fixed-wing aircraft. During the late 1980s, large aerospace contractors went through an initial round of acquiring smaller electronics houses with lineups of sophisticated sensors and electronic countermeasures systems on the theory that future aircraft would be crammed with such equipment (example: Lockheed acquired Sanders, a hot electronics firm, in 1986) and that the market for airplanes would hold firm.

In 1989 the Berlin Wall fell, a year later Germany was reunited, and by 1996 military aircraft purchases had fallen by half. To make matters worse, airline deregulation was squeezing commercial airlines, forcing them to put off new purchases and demand every price concession they could get. Even if a big aerospace firm had a foot in both civil and military markets, the traditional approach to offsetting business cycles—when defense was down, commercial sales were up, and vice versa—it could see no relief on the horizon. And the big firms were still paying the bills for the electronics acquisitions they'd made in the late 1980s.

At the beginning of the Wall Street Decade, the United States had six prime contractors, or "brand name" companies from which you could buy an airliner, a military aircraft, or a large space launch vehicle. By 1998, there were three: Lockheed Martin, Boeing, and Northrop Grumman. But even with the pressure on, the industry required a nudge before it began to consolidate on its own. "In the first two years of 'consolidation,' there wasn't any consolidation," recalls Joe Campbell, managing director of aerospace research at Lehman Brothers, a leading investment bank in New York that has done "well over 70" large deals and claims over half of the merger and acquisition (they call it "M and A") business in aerospace.

One reason for the apparent reluc-

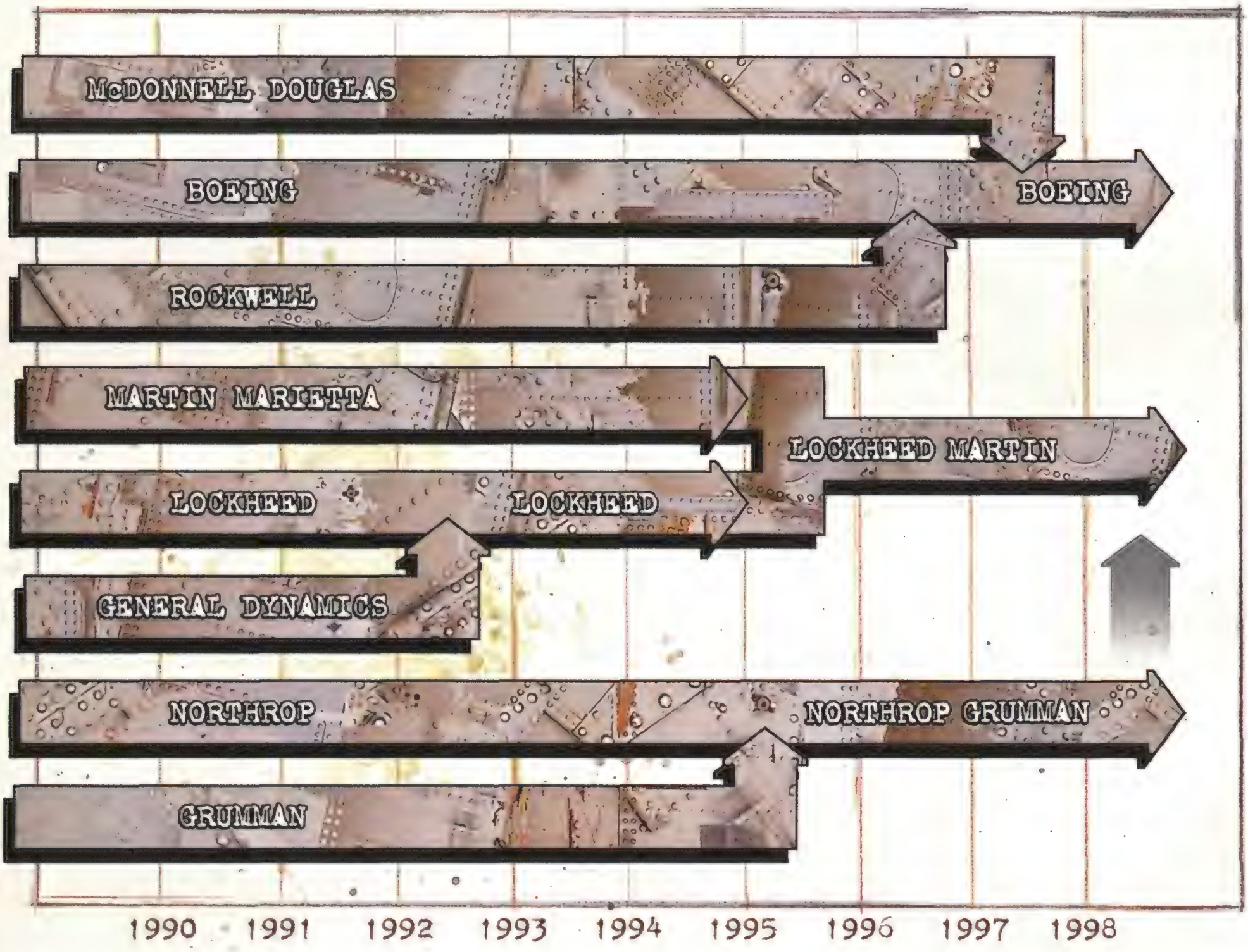
tance was that each company thought it was going to be among the survivors. "It was like Ptolemy telling each of them that they weren't the center of the universe," Campbell says, describing their resistance to consolidation. But the arrival of a new generation of corporate chief executives changed all that.

Aerospace leaders long had a reputation for being sharp in their understanding of technology issues but, to put it charitably, somewhat less sharp in their understanding of business matters. "In the old days, being a good aerospace executive meant being a personable engineer," says Campbell. "They got promoted for being smart, not shrewd.... They were team-playing engineering geniuses, and the best of them had just stepped out of the cockpit."

Not so the new CEOs. They were focused on two goals: making more money for their shareholders, and making more money for themselves. "The new generation of defense managers, while still technically competent, are considerably more financially adroit," Campbell says, "and frankly, the psychological rewards of the old world—'Let's land on the moon'—are still around but greatly diminished. The skills that are needed and rewards that are sought are more financial." In other words, if you can take the steps needed to make your company do well, even if that means selling it, and if you improve shareholder value, you are now as much a hero as the CEO who once set a speed record. A huge cultural change had occurred in these companies, and it was irreversible.

But being a financial hero to stockholders and obtaining just rewards for your good works were not easy in an industry in which the government controlled both profits and executive salaries. The solution, each of these new executives discovered, was to concentrate all resources on boosting the price of his company's stock. There were two strategies: Companies could sell off divisions, accumulate cash, and cut costs by reducing their payroll or they could buy someone else's business, lay off

The Amazing Shrinking Aerospace Industry, 1990–1998



workers, and keep the additional revenues. Either way, the number of companies left standing would be reduced.

The saying in the investment community at the time was "for every Anders there is an Augustine," referring to the respective heads of General Dynamics and Martin Marietta. Former astronaut William Anders adopted the strategy of obtaining top dollar for General Dynamics' aerospace divisions, and his company was one of the first of the big divestors, selling the company's aircraft division (maker of the F-16 Fighting Falcon) to Lockheed and its space launch division (maker of the Atlas booster) to Martin Marietta. Norman Augustine of Martin Marietta was equally determined to dominate whatever aerospace market was left, and he collected companies: In addition to buying General Dynamics' space launch division, he engineered Martin's merger with Lockheed. Today, General Dynamics is out of aerospace but continues to build tanks for the Army and ships for the Navy, and Lockheed Martin is the largest military aerospace contractor in the world.

General Dynamics stockholders were enriched by the proceeds of the sale of such assets as the Fort Worth F-16 production line. Lockheed Martin's stock price rose throughout the same period as its prospects improved, and after the dust settled, the companies had better balance sheets and were more attractive to investors. (And CEO Augustine, another latter-day hero now retired, writes best sellers about how to be a good manager.) If anything, such rich rewards only encouraged more of the same: Boeing scooped up Rockwell, then McDonnell Douglas. Aerospace stocks took off, even as the defense budget plummeted. Once the deals were done, the executives who had options to buy their company's stock at a preset price cashed in.

The heavy lifters in the process that moves such enormous amounts of wealth around are bankers who put up the money to finance multi-billion-dollar deals. It often matters very little to a bank whether an industry's prospects are headed up or down, as long as it's going somewhere. Banks are in the middle of the transaction, so they can make money when the cash flows in either direction. They had their Anders. They had their Augustine. Let the music begin.

At the center of the deal, yet in an odd way sheltered from the deal itself, is a class of professionals—a kind of priesthood—who provide the key financial data to both sides in every deal. These are the equity analysts, and they never had a more important role to play in the aerospace industry than they did during the past decade. In the situation that prevailed during consolidation, when there were too many companies and too much production capacity in a declining market, it takes a certain independence and detachment to advise both buyer and seller, and more important, a talent for helping to envision an outcome in which both sides win.

Analysts are quoted frequently in the business press and often share their views of an industry's—or company's—prospects. Their job is to tell investors how successful companies are today and how much money they are likely to make in the future. During every deal, the analysts are involved every step of the way, advising the financial community whether the deal makes sense, and at what price. The methods they use to do this are a combination of detective work and the connection of seemingly disparate facts.

Banks are in the middle of the transaction, so they can make money when the cash flows in either direction. They had their Anders. They had their Augustine. Let the music begin.

What makes any company's financial picture tricky to obtain is that the analysts almost never get a chance to see the company's current ledger and future forecasts. They may know its history, but a company's past is no sure predictor of its future. Public companies—those that sell stock through exchanges—have to disclose how well they're doing, and no aerospace prime contractor would try to get away with concealing bad news. But analysts are called upon to look deeper than a balance sheet and play out "what if" scenarios using spreadsheet financial models in the same way that accounting software allows homeowners to calculate the results of refinancing a mortgage by inserting different interest rates.

What if Boeing sells 15 more 777s to British Airways? An analyst can add the aircraft to a spreadsheet showing future sales, and the results in revenues and costs ripple through the rest of the analysis. The artistry, therefore, is not so much in their models but in the choice of numbers to plug into the model. "All of the good analysts have some kind of edge," says Jeff Cole, a *Wall Street Journal* reporter who, until recently, covered the analysts who cover the aerospace industry. "They fell out of an aerospace company somewhere and know what's behind the numbers."

Much of the analysts' labor resembles intelligence work. They get some data directly from the companies, then fill in the gaps. "You try to break down items into smaller and smaller units," explains Mark Koznarek, who tracks aerospace companies for Midwest Research in Cleveland. "An aircraft company like Boeing will say, for example, that they project 10 percent growth in earnings. That alone doesn't give you a lot of confidence in how they are going to do it." So he might go to BFGoodrich, which makes landing gear, and ask them, say, what kind of market they expect.

Koznarek knows that every Boeing 747-400 needs parts made by BFGoodrich, including the nose landing gear. If he learns that the supplier's 747 gear production is running behind schedule, he knows Boeing is not going to sell as many aircraft as it had hoped. If he finds out that the supplier has orders for more 747 gear sets than Boeing would logi-

cally need, he knows that the aircraft company is low-balling its sales projections for some reason. Koznarek may have to pull the number he needs out of consolidated production information, so the process is not easy.

Even with these refined computer models, years of experience, and accumulated wisdom, an analyst's assessment usually reflects more than just the numbers. For example, once an analyst gives a "buy" call for a stock, it is harder to later say "sell." His reputation is on the line—especially if the analyst was making a sporty assessment when he first recommended the company. "A lot of them will just ride that stock to its grave," says Cole.

In order to protect the analyst from becoming engaged with the actual buyers and sellers who are negotiating the deal, the banking firm creates a barrier—the slang term in the trade is a "Chinese wall," an allusion to the Great Wall of China and an indication of how formidable this barrier is thought to be. As a deal proceeds, the firm may want the analyst to "come over the wall"—focus on assisting just one side in the negotiations—but once that happens, the analyst can't return to neutral territory again.

Analysts are already peering ahead toward a second round of consolidations involving suppliers and vendors who sell assemblies and rivets and wire to the bigger primes.

An analyst's integrity and reputation are subject to wide scrutiny, and information services such as First Call of Boston collect earnings forecasts from scores of analysts and make them available over the Internet. This collective wisdom serves as the basis for most investors' decisions, so if a company fails to meet the Street's expectations, investors will leave the stock for better prospects elsewhere, and the company's stock price will fall—even if the company is basically sound and has orders stretching as far into the future as a forecaster can see.

Something like this happened to Boeing last fall. Analysts were bullish on the company; it was a survivor, having just acquired its long-time rival in the airliner business, McDonnell Douglas, which left Airbus as its only competitor. Boeing was flush with orders—too flush, in fact. Boeing was taking orders for 747s and 737s faster than its suppliers could deliver parts. It had to suspend production of the two aircraft for almost a month while its subcontractors caught up. The glitch meant that Boeing would build five to 10 fewer airliners by the end of the year. Fewer deliveries meant lower revenues, and when the bad news was announced, the stock price almost immediately fell by 10 percent. Virtually everyone agreed that the company had a bright future, but at least some investors thought they could get a better return elsewhere.

Once an analyst makes a forecast or a stock pick, it's out there for everyone to see. And the game *is* competitive. Those who are wrong too often don't last long. "The grand old men of forecasting are the ones who haven't been fired," observes Cole. Yet that pressure is exactly what analysts seem to like most about the game. "What is really interesting about this business is that every day there is an objective measure of how well I'm doing," says Pierre Chao of Morgan Stanley. "The stock market says whether I'm smart or dumb."

And they do keep score. There are two ranking systems that everyone follows. One, conducted by the magazine *Institutional Investor*, is based on a survey of top money managers and reflects which analysts have the best reputation among the people who use the analysis. The other ranking system, sponsored by the *Wall Street Journal*, compares each analyst's published forecasts, predictions, and stock picks against the actual performance of the market. Equity analysts follow the rankings closely. Egos are at stake, and many analysts have their salaries pegged to their rank. Last year's winner of the *Wall Street Journal*'s All Star rankings was Peter Nisbet of JSA Research. Nisbet's aerospace stock picks last year yielded an impressive 46 percent return on investment, or 13 percent better than the average aerospace analyst included in the survey.

But if there is one aerospace analyst who is generally thought to be at the apex of his profession over the long term, it is probably Wolfgang Demisch, managing director at BT Alex Brown. Demisch has followed aerospace companies for a quarter-century and may be the most-quoted analyst covering the industry.

"It isn't because I have better models than anybody else," says Demisch. He wears a telephone headset with a transceiver clipped to his belt as he walks around BT's 32nd floor offices overlooking the Hudson River in lower Manhattan. A glowing red diode on the transceiver blinks in synch as he talks. "It's simply that you have to be willing to say what you perceive and say it reasonably concisely." Not only is he literally wired to the world through the headset he carries with him, but if you call his company and ask to speak to Demisch, you get Demisch—directly. "I answer my own phone," he says, by way of explaining his success. "So I think just not being filtered has a lot to do with it."

The one thing nobody can predict—not bankers, not CEOs, not equity analysts—is the timing of a cosmic event that changes everything. Lots of people predicted that the Soviet Union would eventually crumble, yet its actual collapse still came as a surprise to the investment community. Some insiders say they saw indications that the government would cause trouble for this year's Lockheed Martin deal with Northrop Grumman, but even they could not have picked March 23 as the day when the government would reverse a policy that had supported mergers.

"We all thought that this was going to be the third and last of the big deals," said Peter Aseritis the day after the suit

was filed, "but there's been a sea change." Aseritis follows the industry for Credit Suisse/First Boston. "The government told Northrop and Lockheed all along that they had troubles with this deal, but management never listened," he said.

Lockheed Martin asked for an early court date to resolve the suit, and Northrop Grumman's stock price fell after the suit was filed, indicating that investors thought the deal was dead. The government argued that the merger will reduce competitiveness in the defense industry and pressed for more and larger divestitures than the firms were willing to agree to. The two sides meet in court in September, and if the differences are worked out, the deal can proceed. Northrop Grumman stoutly portrayed itself as strong enough to go it alone, and the company does have a reported $12 billion worth of both civil and military orders on the books. James A. "Micky" Blackwell, president and chief operating officer of Lockheed Martin's aeronautics sector, told a meeting of the National Aviation Club in mid-April, "The best way to get to [a] lean [operation] is to close facilities.... [In a merger] we will close a company. I don't know whether it will be a Lockheed Martin company or a Northrop Grumman company, but we will close facilities." But despite all the jockeying for position, the market seemed to have sensed a change in wind direction, and the analysts were already re-setting their sails.

The biggest of the big deals are done, and the Wall Street Decade is over—on that equity analysts are virtually unanimous. They are already peering ahead toward a second round of consolidations involving suppliers and vendors who sell assemblies and rivets and wire to the bigger primes. Compared to the Lockheed deal—all $12 billion worth—the banks see smaller fry: "There are a couple at maybe $5 billion, a few at $3 billion, and a bunch at a billion," says Lehman's Joe Campbell.

Most analysts also believe that Europe is the next frontier of aerospace M and A's—if European governments let it happen before the companies are driven out of business. That's a big if: Europe has traditionally relied on aerospace to create much of its employment base, and so far, mergers are running into political barriers. To be fair, many Europeans think they have already consolidated: British Aerospace is all that's left of dozens of proud companies that began merging after they helped win World War II. And on the Continent, French, Dutch, and German firms have already "rationalized"—their word for consolidation—but mostly along national lines; individual nations give up their "sovereign" industries reluctantly. Airbus is the most likely model for Europe's future: one big firm anchored in a united Europe, assuming Europe ever unites.

The beginning of the Wall Street Decade was a time of uncertainty and pain. Tens of thousands of aerospace workers lost their jobs, and the state of California, where a concentration of aerospace industry felt the pain particularly acutely, was hit so hard it looked like it might never recover—but it did (in November 1997, the state's unemployment rate fell 0.6 percent to 5.8 percent, the biggest one-month drop in 14 years). There can be no question that the workers and their families suffered significant personal losses, but the bottom line—so to speak—is that the Wall Street Decade left the aerospace industry in the United States stronger than ever.

{How technology lets you experienc

Agility, as defined by Corv

By Fred Gallasch, Co

Taking one of the world's premier sports cars to the next level of performance is not an easy task, or one we take lightly. Corvette® owners are

{ The 82nd running of the Indy 500® marks the fourth time Corvette has been chosen as the Official Pace Car. }

enthusiasts, and when we consider enhancing their driving experience, we do so with the knowledge that we must do *exactly* that. Esoteric engineering exercises that result in little or no benefit to the driver have no place in the Corvette mission.

What Is Active Handling? Corvette Active Handling is the logical next step in the evolution of enhanced chassis control systems like ABS brakes and traction control. The Active Handling System activates when there is a significant difference between how the driver *intends* for the car to corner and how the car is *actually* cornering. Working with the ABS, it automatically applies any of the four brakes to help actively control the situation.

The Tough Part, Really, Is the Human Part. The thing we've learned about Corvette drivers is that

{The C5 was designed without a roof from the beginning so

it's not only the car's performance that they love, but it's being *in control* too. Active Handling had to be developed to enhance the driver's control without being intrusive. Before we could create

T h e N e x t C o r v e

Corvette to its fullest capability.}

ette with Active Handling.

tte Engineering Group

uld make a world-class sports car that's also a convertible. }

the algorithms for the software, we had to drive thousands and thousands of miles, *anticipating* virtually every driving situation imaginable, not only on dry roads, but on wet and snowy roads,

t t e

too. This is what we mean by the human part. Computers are great. But you have to collect accurate data and set up the computers properly to deliver the kind of driving experience that a Corvette driver demands.

Agility and Subtlety for the Real World. The Corvette Active Handling System offers amazing agility for the kinds of situations you encounter in real-world driving. Imagine a sudden lane change on a wet road surface to avoid an unexpected hazard — like a huge pothole. Let's say you turn the wheel sharply to the left to avoid it. This input, combined with the low-traction surface, could exceed the limits of traction available to the front wheels, causing "understeer," allowing the car to "plow" straight ahead. In this situation, Corvette Active Handling will work to help correct the car's understeer condition by automatically applying the left rear brake, coaxing the car into a left turn. Of course, an aftereffect of this maneuver could be that the tail of the car may actually start to swing out the other way in a classic "oversteer" condition. The subtlety of Corvette with Active Handling is that it responds to this natural overreaction and brings the rear of the car back in line.

A Note of Caution: The overall effectiveness of the Corvette Active Handling System is directly related to available tire traction and the agressiveness of a given maneuver. Active Handling is designed to use existing traction to assist the driver — *but it cannot overcome the laws of physics. Please drive responsibly.*

Competitive Driving Mode for the Track. The Corvette Active Handling System will be the first of its type in the world to offer dual-mode operation. You can engage a *competitive driving* mode

{ Design attributes like the nostalgic waterfall make the new C5 immediately recognizable as a Corvette. }

for autocross, gymkhana or other on-track activities. In this mode, Active Handling remains fully functional — while the traction control is disabled, allowing for some wheelspin and oversteer, so more experienced drivers can exploit the dynamic capabilities of Corvette on the track.

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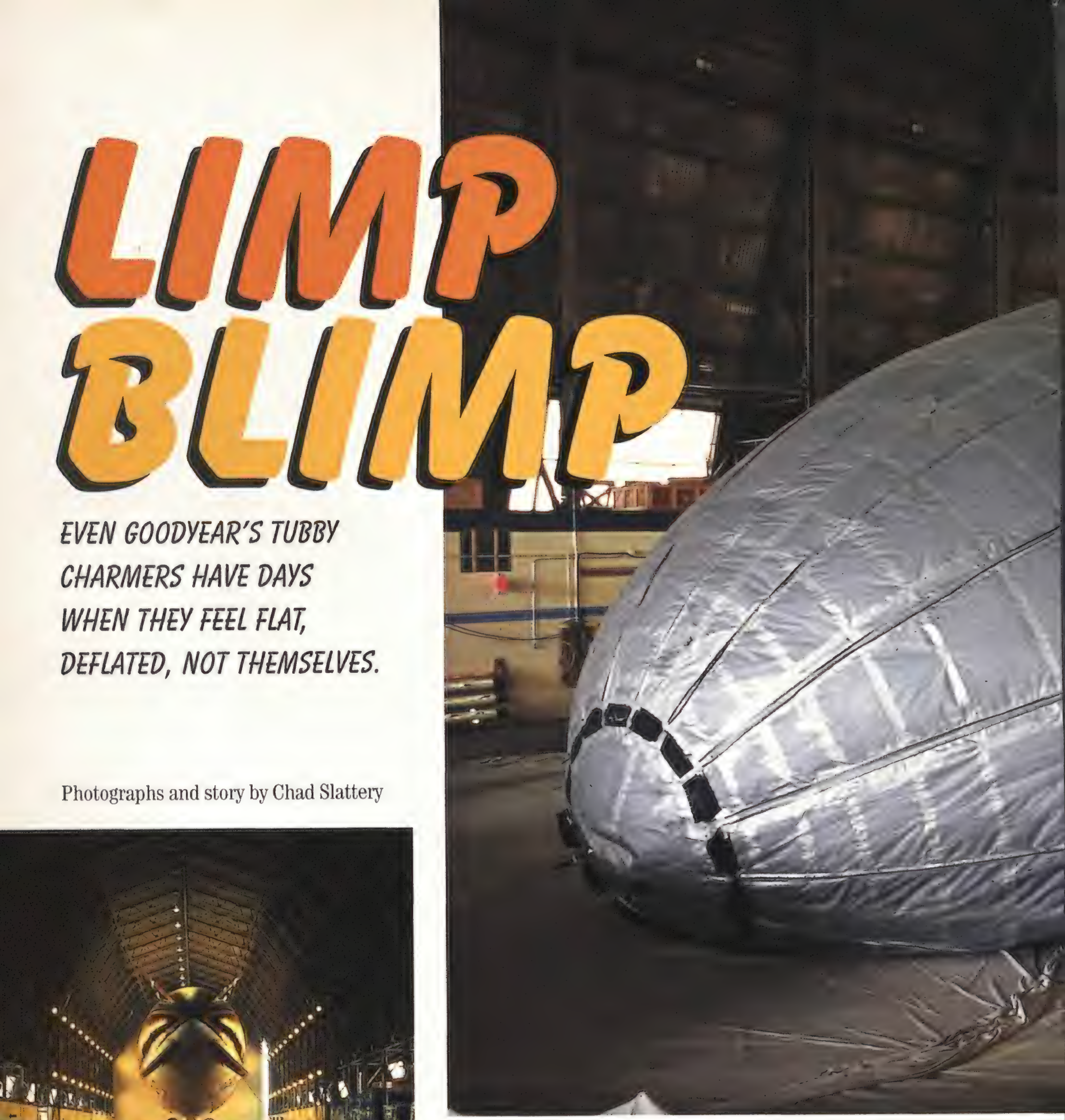
Call 1-800-950-2438
or visit www.chevrolet.com

LIMP BLIMP

EVEN GOODYEAR'S TUBBY CHARMERS HAVE DAYS WHEN THEY FEEL FLAT, DEFLATED, NOT THEMSELVES.

Photographs and story by Chad Slattery



A new blimp envelope lies before the Spirit of Akron *in a Goodyear hangar. Adding helium is the easy part; three months of assembly is required before the envelope will resemble its sister ship.*

They may be the comic relief of the aviation world, seemingly sprung from the minds of cartoonists rather than the laws of aerodynamics, but blimps nonetheless *are* aircraft. And like all aircraft, they wear out and head for the depot.

When a blimp is sent to the hangar, however, it's not overhauled as much as it is resurrected—something that occurs every decade

Partially inflating an envelope into a larva-like shape enables workers to examine its interior surface and structures.

or so for each of the three "aerial ambassadors" the Goodyear Tire & Rubber Company operates. The latest Goodyear blimp to undergo the process, the Florida-based *Stars & Stripes*, is due to rise again this summer.

In refurbished blimps, usually the only major component replaced with a new version is the envelope—the large neoprene-coated fabric bag that contains the helium; other parts, including the gondola, the fins, and the engines, are salvaged from recalled blimps and completely refurbished in a vast hangar at Goodyear's Wingfoot Lake airship base near Akron, Ohio.

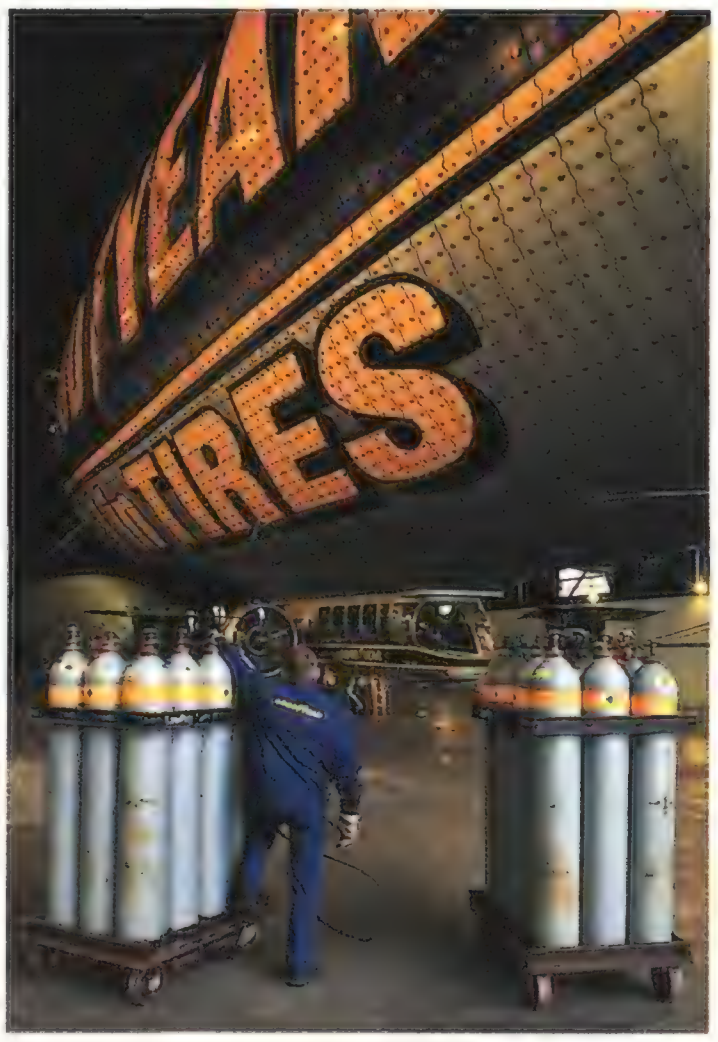
In the hangar under a hand-lettered sign reading "Resurrection Section," airframe and sheet metal repair specialist Don Giblin gestures toward bare, bony fin framework. "Some

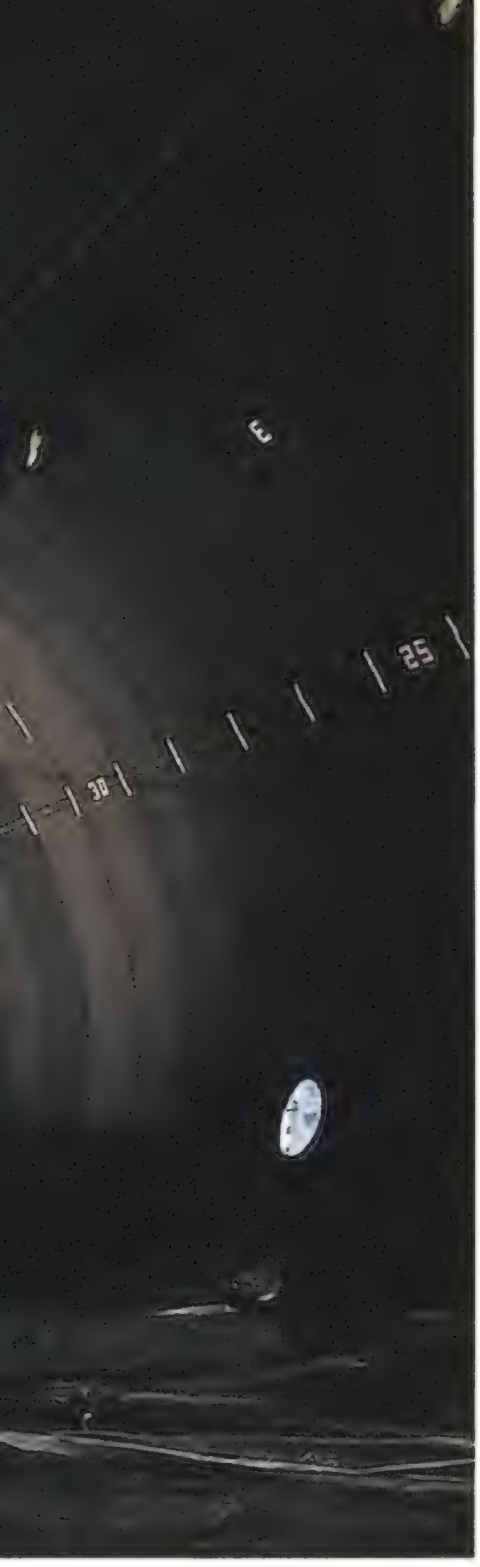
Powerful lamps are used inside the envelope during inspection (top); light escaping on the other side will reveal any holes. The envelope isn't the only component requiring painstaking work. Metalworker Don Giblin is restoring a decades-old lower fin.

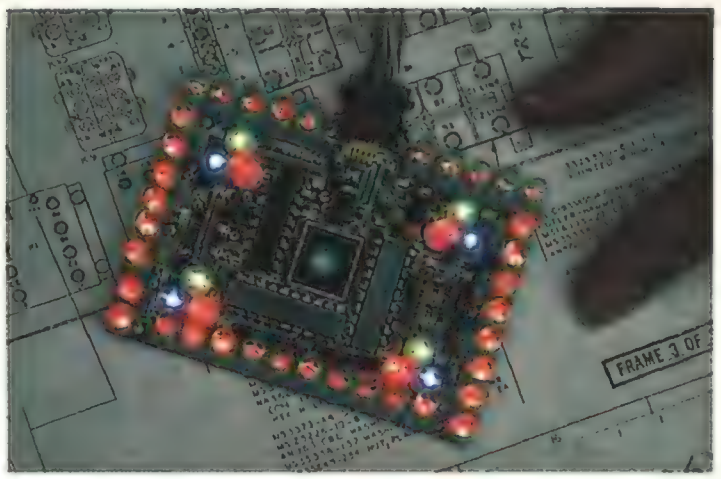
of these go back to 1940," he says. "The one I'm working on has flown on six different blimps. There are no jigs here," he adds as he sets down a 1930s-era rivet squeezer. "Everything is hand-fit."

Throwbacks abound in the world of the blimp, where pulleys and cables still control rudders and doped fabric still covers the fins. Goodyear's newest airship type, the relatively sleek GZ-22, completed in 1987, flies exactly 4 mph faster than the company's Type C blimp did eight decades ago. "We've got 75 years of tradition uninhibited by technology," jokes radio technician Stanley Pike.

There is one area, however, where blimps have something in common with their higher-speed kin: They, too, have been subject to the recent spate of aerospace mergers. When Goodyear sold its Aerospace division to Loral—subsequently acquired by Lockheed—in 1987, the blimp engineering and manufactur-







ing operations went with it. Although Goodyear has manufactured nearly 350 blimps since its start in the business early this century, today it would have to order a new blimp from the company that owns the blimps' type and production certificates: Lockheed Martin (or from one of the handful of other blimp manufacturers in the world).

But that won't be necessary any time soon. Goodyear has a wealth of spare parts. At the Wingfoot facility, a tiny core staff refurbishes them year-round. "The process is constant, continuous," says John Moran, pilot-in-charge of the *Spirit of Akron*, which is based there. "Every time we finish refurbishing one airship, there's another one that needs to be done."

Goodyear recalls a blimp when its envelope—or bag—starts to deteriorate. Bags last between 10 and 12 years. To keep its fleet of three in the air, Goodyear, with assistance from Lockheed Martin, assembles a replacement blimp every three or four years.

The resurrection begins with a careful inspection of the new envelope. Created of polyester fabric imported from England, coated with neoprene at a Goodyear facility in Nebraska, and cut and stitched together at a Lockheed Martin plant in Georgia, the envelope is folded and trucked to the Ohio hangar in a 12- by 12- by 20-foot box. Because the folding and shipping can take their toll on the envelope, technicians at the receiving end inflate it to 60 percent capacity and inspect its football-field-sized surface for holes, which they mark and patch. Next they rig the internal suspension cables that will hold the passenger gondola, fully inflate the envelope to make sure the cables are the proper length, then let it gradually deflate so the cables will gently coil upon themselves.

They then cover the envelope with a net anchored with sand bags and inflate it with helium, a process that takes about four hours and over 200,000 cubic feet of helium. Next, they attach the gondola beneath it and paint the envelope, moving the net as the work progresses. Finally, the fins, nose cone, and night sign go on. The assembly takes about 25 workers three months to complete.

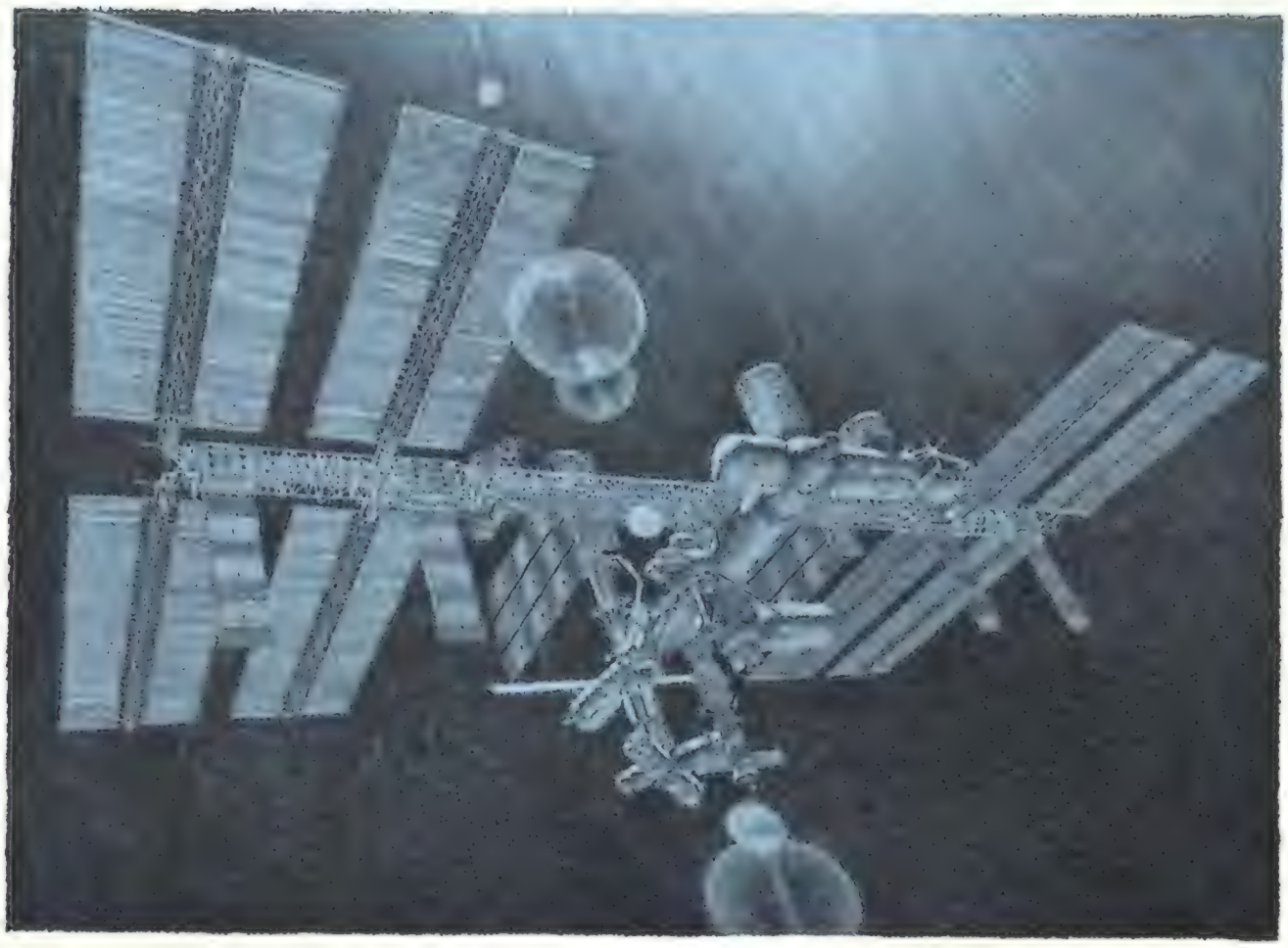
The finished airship will then assume the name, the place, and the crew of the one being recalled, which is turned over to the Wingfoot staff. They release the helium, dispose of the bag, and ready the components for yet another cycle of renewal.

Even new envelopes leak helium and must be topped off about once a month (left), with greater amounts added in winter as the gas contracts. Though blimp technology has changed little over the years, there is one splashy new addition: the Spirit of Akron's *new LED display, undergoing testing at dusk. Consisting of 3,854 "boards" (top, right), the sign has a palette of 32,000 colors.*

HOUSTON,

(and Moscow, Munich, Tokyo, Montreal...)

Mission control gets ready for the international space station.



by Marcia Dunn

Illustrations by Carter Emmart

It was Friday afternoon and Russia's Mir flight controllers were headed out the door as usual, even though the space station's oxygen-generating system had just collapsed. To the astonishment of NASA flight director Bob Castle, who was monitoring everything from the Johnson Space Center outside Houston, the team planned to deal with the problem on Monday.

Castle remembers asking, "What do you mean? Why aren't you working on it now?" Then NASA's own environmental expert assured him that Mir's three-man crew had 10 days' worth of oxygen remaining and that there was, indeed, no need to rush.

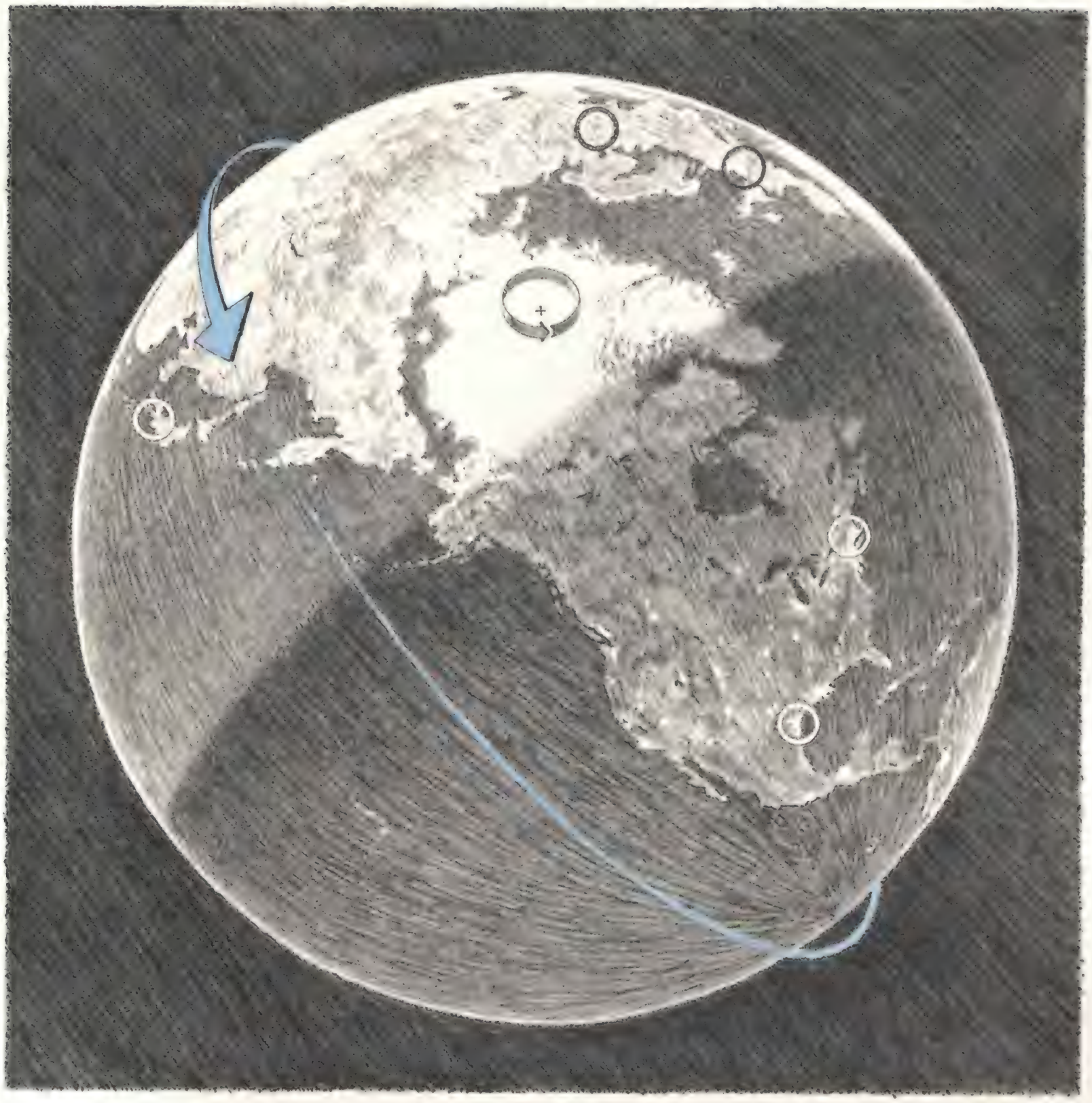
Come Monday morning the problem was fixed, as the Russians had promised. And Castle and company had learned an important lesson for the international space station: If something can wait, let it. Take your time and do it right. In general, lighten up.

"Is it a little different from working Shuttle? Yes it is," says Castle, recounting the 1997 incident. Will NASA be able to make the adjustment? "I don't think it's going to be as hard as people believe," predicts the man who will direct the second international space station (ISS) assembly flight from shuttle mission control in Houston.

This fall, after years of bartering and bickering, NASA and the Russian Space Agency hope to start hauling parts of the station into orbit. At the same time, two control centers—located 6,000 miles and nine time zones apart, with different languages and customs—will begin 24-hour-a-day operations that will continue, according to current plans, for some 15 years.

Both sides agree that without the shuttle-Mir program, appropriately named Phase One, the task of melding the two countries' contrasting—some would say clashing—approaches to spaceflight control would have been a mess. Valery Ryumin, director of Russia's Mir-shuttle program and a veteran cosmonaut, thinks the learning has

WE HAVE A PROBLEM



been especially heavy on the U.S. side. The Russians, after all, have been flying Mir for 12 years, and before that operated Salyuts 1 through 7. The only U.S. space station has been Skylab, which was inhabited off and on for less than a year in the early 1970s. Then it was on to the frenetic pace of short space shuttle flights.

"It took us years to reach this point, of course encountering difficult situations and getting bruises," Ryumin says of the Russian space station experience. "The U.S. side will pass this way much faster because there is somebody to help." Then he can't resist throwing in a little jab. "Even a bear can be taught to play a musical instrument," he says in Russian, chuckling.

Russian and American space engineers have learned a lot about one another, personally and professionally, since the first shuttle-Mir encounter in 1995. For Russians, fancy NASA titles like "Attitude Determination and Control Officer" don't count for much. Integrity does. "The Russians are very, very focused on individual relationships," explains NASA flight director Phil Engelauf, who has presided over several shuttle-Mir missions. "They want to work with you because they know you and they trust you. It's just a Russian cultural style."

Another Russian style: publicly criticizing NASA. The deputy chief of Rus-

sia's mission control, Viktor Blagov, in particular likes to "ring your bell," says one NASA manager who asks not to be identified. He describes Blagov as extremely competent but odd in the delight he seems to take in complaining about NASA to Russian reporters. "He can grouse and blame things on us that are just silly," the manager says.

The space agencies of Japan, Europe, and Canada—the station's other major partners—have observed these goings-on with considerable interest and, on occasion, amusement.

"On how many shuttle missions has everything happened between 8 and 5?" asks flight director Bob Castle. "It's always going to be in the middle of the night for somebody."

"We find no difficulties working with the big two elephants," says Akira Nakanishi, director for special coordinations for the National Space Development Agency of Japan. If NASA and the Russian Space Agency are the size of elephants, then how big is the Japanese agency's role in the space station? "Bigger than a dog," Nakanishi laughs.

It will take about five years and 45 launches to piece together the station's 100-plus parts in orbit (see "Some Assembly Required," June/July 1997). Russia will be first at bat with the launch (on a Proton rocket) of a Russian-built, U.S.-financed control module that provides the station's initial propulsion and power. NASA will follow within a few weeks, ferrying up a multi-port connecting passageway that engineers call a node but that recently was given the name Unity.

With the launch of the first module, U.S. and Russian control centers will begin simultaneous round-the-clock operations. For that launch, as many as 10 NASA workers will be assigned to the control room in Korolev, outside Moscow, and an equal number of Russians will be on hand in Houston. Controllers in both countries will be monitoring computers, heaters, power generators, and other station subsystems. The plan for this early phase when the station is mostly unoccupied is for only a handful of people to remain on duty during quiet times between shuttle visits.

Once the first three-person crew moves in with the sixth assembly flight next year, Castle expects that during peak times, eight people will staff the control center's front room and at least eight more will be in behind-the-scenes support rooms, a kind of proving ground for flight controllers. That's just one-third the staff—and consequently one-third the cost—required to run the space shuttle. The Russian control center will have no more than 18 people on duty at any time.

The space station needs fewer flight controllers for one simple reason: It never returns to Earth until the day it's brought down to die. Every minute the shuttle is in orbit, on the other hand, mission control has to be prepared for an emergency landing. A specialized entry team also is brought in for the so-called nominal landing at the end of a mission.

Another reason the Houston team will be smaller is that NASA will be sharing space station control duties with the Russians. There also won't be time for the extensive rehearsing that precedes all shuttle flights, nor should there be. "Station is a different animal," says Bill Reeves, a lead flight director for ISS who worked as a flight controller for Apollo. "It's designed to be more forgiving, and that provides you the opportunity to do a little more trial-and-error work, to scratch your head a little more and think about what you're going to do next."

NASA's ISS flight controllers will work eight-hour shifts, with three teams covering a 24-hour period as they do for the shuttle. Russian flight controllers plan to stick with the long shifts used for Mir: 24 hours of straight duty, then three days off. Grueling as it sounds, it suits the Russians just fine and NASA has no objections.

During the station's early assembly phase, the Russian control team will handle daily operations because most of the orbiting elements will be Russian. Nevertheless, the U.S. flight director on duty—Castle and Reeves will be among those taking turns—will always have the final say. When the first crew members arrive, the Russian flight director will manage them and decide their work schedule. Once the U.S. laboratory module is launched four months later, NASA's mission control will assume those duties for good. The laboratory will contain the brains and nervous system of the station, thus the shift in responsibility.

Reeves expects it will be hard for the Russians to relinquish authority once the U.S. laboratory is flying. "Sure it's going to hurt," he says. "They talk about it a little bit, but they try to avoid [the subject]."

NASA's terrestrial nerve center for the station is just down the hall from the new, blue mission control used for shuttle flights. It too is new and blue and equipped with the latest in off-the-shelf computer technology. The room, known as the special vehicle operations room, could be converted into a shuttle control center by simply changing the computer software at each console. With yet another software swap, it could someday be used to send astronauts on a mission to Mars.

Although some planning is already

under way, the station control center won't begin realistic mission simulations using the new software until this fall, not long before actual operations begin. "We're starting back at the beginning," says Castle. "We're going to get surprised by how the hardware behaves and how the software behaves on the station. We're going to be surprised by how things behave in the control center because we haven't run them that much."

The Russians, on the other hand, will run ISS out of the same building they've always used for controlling Mir and from which most of the Salyut stations were monitored. They'll start with a small control room and then switch after several months—once their all-important service module is launched to equip the station with life support systems—to a room used in 1988 to control the one and only flight of the unmanned Buran shuttle.

The Korolev center goes by the acronym TsUP, pronounced "soup." Its overriding hue is gray, just like the sky outside on most days. Unlike NASA's mission control, tucked deep inside the secured Johnson Space Center, the Russian center is located in a nondescript neighborhood outside Moscow. Visitors can drive right up to the building and walk in.

These two main control centers—eventually to be joined by centers in Japan, Europe, and Canada—will be linked by phone, video, and computer. Although controllers will be spread across multiple time zones, Castle doesn't anticipate coordination problems if trouble strikes at an odd hour. "On how many shuttle missions has everything happened between 8 and 5?" he asks. "To me, it's not going to be any different. I'll have the same number of people to call as I would on a shuttle mission. And okay, the Russians will call some people and the Japanese may call someone, depending on what it is. But it's always going to be in the middle of the night for somebody."

The station, once it begins routine operations, will run on Houston time. And English will be the official language, both in space and on the ground. Russian- and English-speaking interpreters will be standing by in both Houston and Moscow, at least for the first few years. "You've got to be realistic," says Castle. "There are people in Russia's mission control center, very valuable, who have never spoken English. They're not going to learn overnight and you just can't shut them out."

Some of NASA's designated station controllers, like power systems specialist Tim Propp, are studying Russian to better communicate with their Moscow counterparts. It's recommended but not required. Japan's space agency, on the other hand, will expect its flight controllers to be fluent in English as well as in what the agency's Nakanishi calls "flight dialect."

"We need to learn all of the technical tongues" by the time the Japanese Experiment Module is launched in 2001 and the Japanese control center simultaneously begins operating around the clock, he says. To learn the ropes, the Japanese agency hopes to send personnel to the Johnson Space Center once full-fledged station simulations begin this fall and to have a NASA flight director visit its not-yet-completed control center outside Tokyo.

The Canadian Space Agency's control center, located near Montreal, will crank up with the launch of that country's robot manipulator arm for the station in 1999. And the European Space Agency will open one, and possibly two, control centers once its Columbus laboratory module and first automated transfer vehicle (a cargo ship launched on an Ariane rocket) are flying in 2002.

A leading contender for one of the centers is Oberpfaffenhofen, outside Munich. The German space agency DLR built a control center there in the early 1990s and equipped it with four main control rooms, along with simulators for training flight controllers. The new center made its debut with a U.S.-German Spacelab shuttle mission in 1993, and was used to support German guest flights on Mir in 1995 and 1997. Design of a Columbus Orbital Facility control center has already begun—Germany hopes ESA will give it the nod to start converting the existing center to a space station center next year.

The space station will be the first U.S. piloted spacecraft to be inaugurated while an old one, the shuttle, is still in operation. So when *Endeavour* is launched on the first U.S. assembly flight, both of NASA's mission controls will operate nonstop until the shuttle returns. Then only the ISS control room will keep going—and going—until the next shuttle flight, when both centers will again be pressed into service.

Staffing the station control center will be a mix of newcomers and shuttle veterans—a slightly different approach from the one NASA has taken in the past. When Castle worked on STS-1, the first flight of the shuttle, "I was in one of the back rooms and the front room was full of Apollo veterans," he recalls. This time, with the overlapping operations, "we can't just take all the shuttle veterans and put them in station because then you don't have anybody to operate the shuttle."

The shortage of old hands will spell opportunity for others. "The younger people bring in fresh ideas," says the 30-something Propp, who will make his flight control debut with the station. And sometimes the old way may not be the best way.

NASA, for example, has thrived for decades on redundancy. Every decision is accompanied by reams of paperwork and approvals all the way up

a lengthy chain of command. Every day of a shuttle mission is carefully choreographed, every move by the crew planned down to the last little detail. "There's no doubt about it, we make folks work as hard as we can," says flight director Engelauf.

While an intensive, hands-on approach may work for shuttle flights that last two and a half weeks tops, it's impractical for running a space station. "You can't do that for 365 days a year," Engelauf agrees. "Crews would turn off their radio about two weeks into the flight and you'd never hear from them again until it's time to come home."

Station flight director Jeff Hanley, a former shuttle payload officer, doesn't expect it to be a difficult transition for controllers. The station crew and ground will work together to schedule major activities but will also have a flexible "job jar" of do-anytime tasks. Shuttle astronauts assigned to Mir dockings have already had more leeway in determining their schedules, especially when it comes to moving equipment.

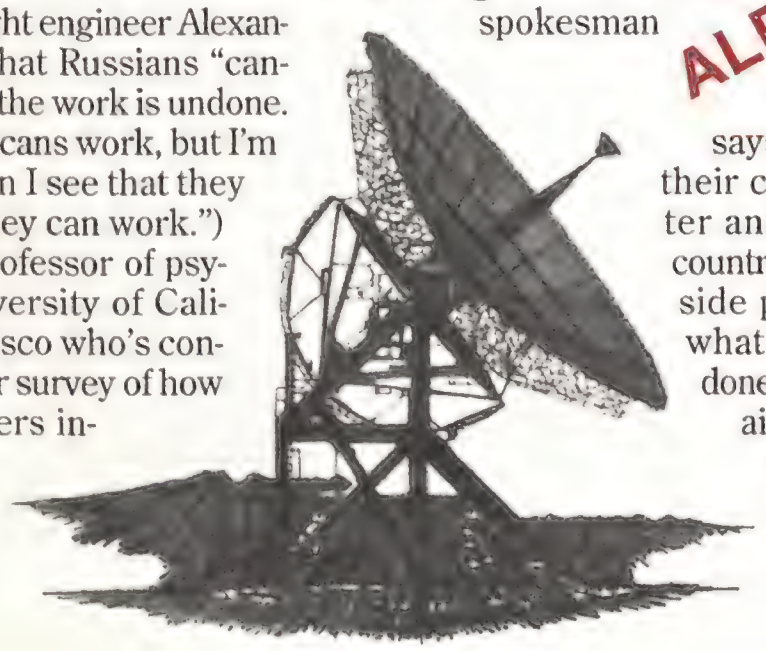
Shuttle commander Terry Wilcutt experienced the more relaxed approach to scheduling firsthand. He was surprised—happily so—at the ease with which Mir's cosmonauts welcomed him and his crew during a short visit in January. The shuttle astronauts were ready to start work as soon as the hatches opened, but the station cosmonauts insisted that everyone first have something to eat and drink. "It's a tradition where you sit down around the table and talk, and then you get to business later," Wilcutt says. "That's certainly a cultural difference between us, and probably one we could use a little more of." (Cosmonauts may have their own take on the contrasting approaches to time management: In an online interview last October, Mir flight engineer Alexander Lazutkin said that Russians "cannot really rest when the work is undone. I like the way Americans work, but I'm very surprised when I see that they don't work when they can work.")

Nick Kanas, a professor of psychiatry at the University of California at San Francisco who's conducting the first-ever survey of how space crew members interact with one another and with flight controllers, sees scheduling as one example of the two former rivals learning each other's approaches to spaceflight. "Both sides have been changed for the positive and are developing their own cultures that are common to the two sides," he says.

"You've got to be realistic," says Castle. "There are people in Russia's mission control center, very valuable, who have never spoken English. They're not going to learn overnight and you just can't shut them out."

The Russians don't go for constant direction of space crews from the ground, in part because of the spotty communication link between Mir and the TsUP. Conversations between ISS and mission control will sound like a gabfest by comparison, once more-capable NASA relay satellites are in use. But things won't be nearly as chatty as they are with the shuttle. NASA wants to be more like Russia in that regard, talking with crews only when necessary so as not to bug them.

The public affairs commentary that now accompanies shuttle missions practically nonstop will drop off too, once the station settles into an orbital routine. The press will still be able to follow the action, though, at least in the United States. Russian space officials, stung by what they saw as exaggerated reporting of Mir's problems last year, decreed in April that journalists can no longer listen in on conversations between Mir cosmonauts and the ground. NASA spokesman James Hartsfield says only, "It's their control center and it's their country." The U.S. side plans to do what it's always done, leaving the air-to-ground conversations open for anyone to hear.



Every weekday morning and evening, the astronauts and cosmonauts will "meet" with flight controllers via video to discuss work and personal matters. For these video conferences, the ISS crew will hook up a laptop computer to outlets in the Russian control module, the first component to be launched. Once a higher-capacity Ku-band antenna is up and running on the station later next year, crew members will be able to talk from elsewhere on board.

They also will be talking to more people, in more places, than they ever have before. This marks a shift from the old days, when astronauts communicated only with Houston or NASA's Marshall Space Flight Center in Alabama, which handles science operations for shuttle missions and will continue in that role for the ISS. Spacelab flights have pioneered the use of "telescience," whereby scientists can in some cases talk directly to the astronauts from home laboratories or universities. NASA is considering the use of voice communications over the Internet to make this type of interaction even easier and more common.

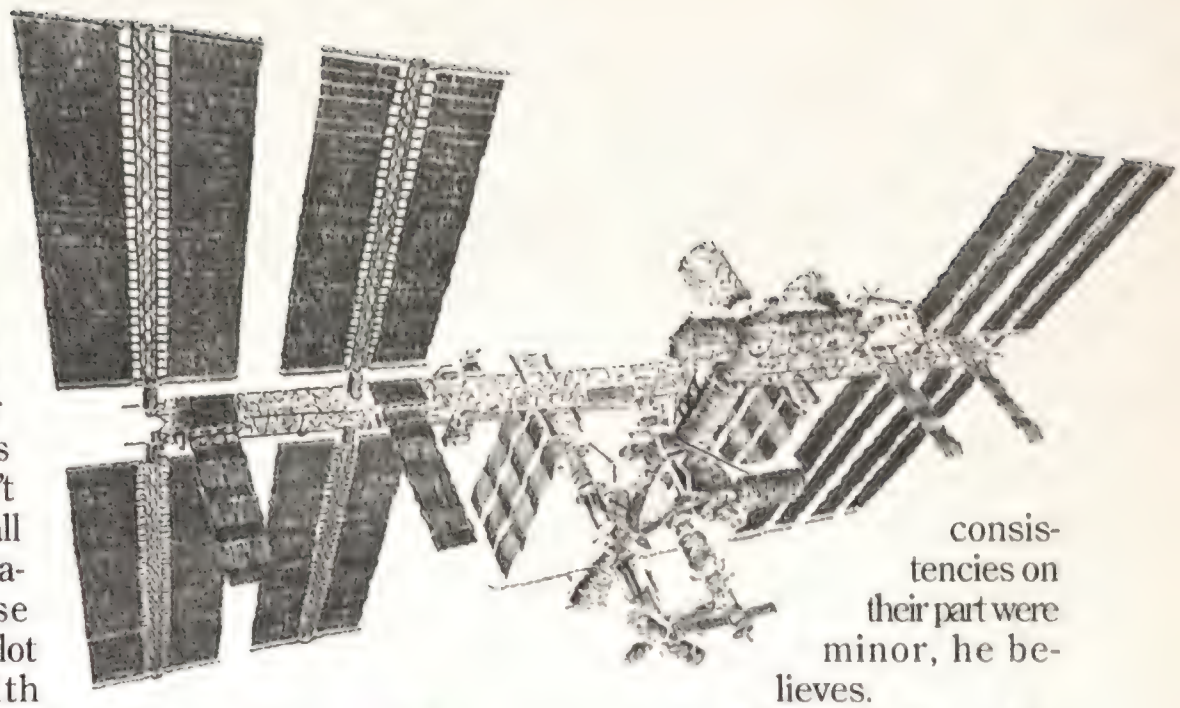
With so many players involved in such a complex operation, ISS crew members will have to abide by a space station code of conduct agreed upon by all participating countries. This code, still in draft form, will outline not only the chain of command and responsibilities in orbit, including the commander's authority to enforce safety procedures, but the relationship between the crew and ground controllers. The flight director, for instance, will be

responsible for handling most problems involving the station and the overall mission. But the onboard commander will decide what to do in emergencies such as fire or decompression—current policy for Mir as well as for the shuttle. The commander also will call the shots on board the station, even when a shuttle skipper is there. Command of the early space station missions will alternate between astronauts and cosmonauts, with the remaining two crew members coming from the opposite side.

The real compatibility test will be how problems—especially emergencies—are handled on the ISS. Shuttle controllers tend to go by explicit, established rules that dictate when the crew should try to solve a problem, and when for safety's sake they should return home. On Mir the rules are not as strict. Lazutkin, in his online interview, admitted that "when we had the fire and the pressure level dropped, in accordance with written instructions we had to leave areas of the station." But they stayed and fought the fire instead. "Theoretically we were breaking some rules," he said. "But we were realizing what to do, and that was probably the main thing."

Instead of forming NASA-style tiger teams every time something breaks on Mir—they have neither the personnel nor the money to do so—Russia's flight directors call in experts who tend to come up with quick, unpretentious solutions. "We have a lot more manpower to throw at a problem than they do," explains NASA's Engelauf. "And I don't want to say we do it without regard to the cost, but we do things because we think that's the right thing to do." By comparison, he says, the Russians are "very, very, very, very cost-conscious."

NASA is now developing its own rules for the station. While visiting the TsUP late last year, Tim Propp and other future station controllers spent several days explaining the proposed rules to their hosts. The Russians were amenable. But when the NASA controllers offered to give the Russians all the power-supply data to be transmitted from the U.S. components during the early assembly flights, the Russians balked. "Their response was basically 'I don't need to see all that information because there's not a lot I can do with that information. Just show me the basics of the system—the current, the voltage,' " recalls Propp. Returning from Moscow, he says, the NASA engineers felt that they had established a good working relationship with their partners.



Things don't always go so smoothly. In an internal NASA memo issued in 1997, the most problem-plagued year in Mir's existence, Engelauf criticized the performance of Russian flight controllers. He cited a cosmonaut error—Lazutkin's pulling of a plug associated with a key computer that controlled the station's orientation—that was made worse by a seemingly indifferent mission control. What's more, Engelauf wrote, the cosmonauts and controllers tended to communicate poorly. The cosmonauts, for instance, were not taken seriously when they reported the computer failure. These were the same two men—Lazutkin and Vasily Tsibliev—who endured not only a terrifying fire but a near-disastrous collision with a cargo ship. NASA astronaut Jerry Linenger was on board during the February 1997 fire, his replacement Michael Foale during the June 1997 crash with the cargo vehicle.

Lazutkin says he wasn't stressed out or exhausted when he made the error, and he sticks up for the ground crew. "There were many cables that were to be unplugged, so with one of the cables I made a mistake on the timing," he explained through a translator during a U.S. visit earlier this year. As for the response of the flight controllers, "they're only human beings...people can make mistakes," he says. Any inconsistencies on their part were minor, he believes.

Foale, who was on Mir when Lazutkin yanked out the cable and set the station adrift, says the Russian controllers were polite during the crisis. But he notes that U.S. astronauts have more input into missions than do cosmonauts, and are probably more in synch with the ground team than Russian crews are. "The cosmonauts are trained in a separate place, away from the developers of the hardware and the people who develop and control the flight," he says. "As a result there has been less feedback, I would say, back from the cosmonauts to the institutions that are using them to execute their program."

Engelauf admits his memo was critical. "But one of the things we're doing in Phase One is trying to learn how the Russians do business and how that's different from us," he says. "We're going to do some Monday morning quarterbacking. And if anybody thinks that memo was harsh or rough, he has never heard me debrief my own flight control team after a sim [simulation] or after a flight."

Kanas, the psychiatrist, views all this as normal growing pains. "There are things to work out and there will be negotiating to be done," he says. "But I think in the end, when we look at it down the road, they'll figure out a way to work with each other."

Both sides say that Mir's travails, for all their commotion, have proved to be a boon from an educational point of view. "It's kind of paradoxical," says astronaut David Wolf, who lived on the Russian station for four months last year, "but without the problems it would not have forced the interactions that we did get and the value we've received from those." Of course, his stay on Mir was a relatively quiet one.

Hawk-eyed, falcon-fast,
and owl-smart, the F-22 Raptor
redefines air superiority.

The 21st Century Fighter

by Fred Reed

At 10:18 a.m. on September 7, 1997, two huge engines roared to life at Dobbins Air Reserve Base in Marietta, Georgia. Minutes later, a gray shape began to roll down the runway. Lockheed Martin test pilot Paul Metz eased back on the side stick, and for the first time, the company's F-22A Raptor took to the air. With two F-16s flying chase, Metz took the aircraft to an altitude of 20,000 feet, never exceeding an airspeed of 290 mph before landing 58 minutes later. Metz, who has spent the last four years working with project engineers to refine the flight performance and handling of the F-22, said of the Raptor's first trip out of the nest: "The airplane performed right on prediction. It's what I expected. It's what I wanted."

He's not the only one. The U.S. Air Force wants to buy an entire flock of Raptors—339 birds in all. Scheduled to become operational in 2005, the F-22 is the Air Force's bid for absolute air superiority for decades to come. Occasionally an airplane makes a leap that renders previous aircraft obsolete—the German Me 262, the first jet fighter, for example. The Raptor, the Air Force hopes, will be one of those airplanes. With a cruise speed of better than Mach 1.5, sophisticated sensors, and a high degree of stealth, the Raptor aims to routinely detect and destroy enemy fighters from far beyond visual range without ever being detected itself. This tactic, which the Air Force refers to as "first-look, first-shot, first-kill," is the key to future air superiority.

The F-22 is the outcome of a long debate over what an American fighter should be, the distillation of late 20th century experience with air combat, and the consequence of much thought about what the United States will and won't tolerate in war and what kind of enemies we will have. It is not just the patching together of the biggest engines with the fastest computers, but a calculated combination of abilities that, working together, make the F-22 a new approach to air combat.

The Air Force's current air superiority fighter, the McDonnell Douglas F-15, has never been shot down by another aircraft in any war in which it has flown. It first took to the air on July 27, 1972, and only a year later, the Air Force was already starting to envision its replacement, what would eventually materialize as the F-22. "There has always been a knowledge that when a new airplane enters service, its successor should already be beginning to march across a drawing board," says U.S. Air Force chief historian Richard P. Hallion. "You cannot wait until an airplane is obsolete before beginning to search for its successor."

The design of the F-15's replacement would be shaped by the types of threats employed in two regional conflicts, the 1972 air war against North Vietnam and the 1973 Arab-Israeli war. Both the North Vietnamese and the Arabs used integrated air defense systems—radar-guided surface-to-air missiles and anti-aircraft artillery—to shoot down incoming aircraft. Egypt's Soviet-made air defense system badly wounded the Israeli air force, which lost 109 aircraft

The F-22 Raptor looks like an F-15, but that's where the kinship stops: With its stealth, intelligence, and maneuverability, the F-22 outclasses all other U.S. fighters.

JAMES HOLCOMB/NICK ALVARADO LOCKHEED MARTIN

in 19 days. With a combination of better tactics and better electronic countermeasures, the Israelis minimized future losses and managed to win the war, but the lesson wasn't lost on the rest of the world's air forces. So early on, building a fighter that was less visible to powerful ground-based radars was high on the Air Force's wish list.

In Vietnam, of course, U.S. pilots had to worry about more than just surface-to-air missiles; there was also the air-to-air threat posed by Soviet-made fighters such as the MiG-17, -19, and -21. Air Force tacticians, realizing that if opposing pilots see each other at the same time they have something resembling an even chance of killing each other, responded by equipping their own aircraft with more powerful radars and longer-range air-to-air missiles—an early attempt to give fighter pilots a first-look, first-shot, first-kill capability.

"It's much better to detect the other guy and take him out than to get into a furball [a turning, close-range dogfight] and arm wrestle with the guy," says Al Pruden, Lockheed Martin's F-22 program manager for advanced product development. Pruden, who flew F-4s in Vietnam, elaborates: "The problem was we would invent a radar and the enemy would also have radars that were reasonably close to the capability of ours, so that when you were going against comparable airplanes, both pilots saw each other roughly at about the same time and you always ended up in a furball even though you didn't want to." To make matters worse, the F-4s deployed in the early part of the war didn't even have guns, leading to what Americans considered a dreadful one-to-one loss rate, which eventually improved to a still undesirable 2.4 North Vietnamese aircraft downed for every one U.S. aircraft lost.

Of the air war waged in Vietnam, General Richard E. Hawley, commanding officer of Air Combat Command at Langley Air Force Base in Virginia, says: "We watched this country lose 2,400-plus fixed-wing aircraft, in part due to a flawed strategy but partly because we had to fight for air superiority every day with inadequate equipment. We used the stuff we had when that war started, F-100s and F-105s, and eventually we bought a lot of F-4s, which of course had been built and designed as a fleet defense fighter for the Navy. We came out of Vietnam saying, 'We ought to do better than that.' "

This determination led to the F-15 and the General Dynamics F-16, a lighter, more maneuverable, fly-by-wire multirole fighter. But Air Force leaders couldn't rest easy; by 1980 they received intelligence reports that the Soviets were hard at work on fighters that could challenge the F-15. In November 1981, the Air Force formally stated its need for an advanced tactical fighter (ATF) to replace the F-15. "We had to make sure that we were not caught short," says Pruden, who retired from the Air Force in 1986 as director of safety before joining Lockheed.

In 1983, the Air Force awarded ATF concept definition contracts to seven airframe companies: Lockheed, Rockwell, Grumman, Northrop, McDonnell Douglas, Boeing, and General Dynamics. Three years later, the Air Force decided to fund the development of two prototypes, the YF-22 and YF-23, which would be built and flown by two competing teams: Lockheed-Boeing-General Dynamics and Northrop-McDonnell Douglas. By using this "fly before you buy" method to acquire a new airplane, something it had rarely practiced since the early 1960s, the Air Force hoped to minimize the risks of purchasing untried technology.

Acquiring a new fighter is an extraordinarily complex process that begins with what Air Force tacticians perceive the threat to be. When Air Force planners look into the future, notes Tom Burbage, Lockheed Martin's F-22 program manager, "they kind of blue-sky things that aren't necessarily within the grasp of technology at the moment. The reason they do that is to force technology to reach." He is referring to what those in the industry call the "requirements push/technology pull" equation.

In 1981, when the Air Force set in motion the process that would lead to the F-22, the threat was more easily identified than it is today. The main concern of the U.S. military community was what the

NASM (2)

The air superiority ancestry of the F-22 includes the North American F-86 Sabre, the Air Force's first swept-wing fighter (above), the McDonnell F-4 Phantom II, which began as the Navy's F4H interceptor (below) before playing a leading role in the air offensive against North Vietnam, and the McDonnell Douglas F-15 (opposite), which scored 38 kills in the Gulf war.

Soviet army or air force might do. "The bipolar world that we had during the cold war was extremely predictable," says Hallion. "And in its own way, it was extremely stable." Now, in a more fragmented and unstable geopolitical environment, the number of threats has multiplied with the number of ethnic, religious, and geographic rivalries. Today there are many air forces to worry about. Compounding matters is that with the end of the Soviet Union, an economically weakened Russia has resorted to earning hard currency by selling all manner of weapon systems, leading to a global proliferation of Soviet-era fighters and air defense systems.

Fighters available on the world market, such as the Sukhoi Su-27 and the MAPO MiG-29, are in the same class as the F-15. And parity in aircraft quality might, against competent enemy pilots, lead to an unacceptable parity in casualties. The goal is not parity but overwhelming superiority. "We don't want a fair fight," says Tom Burbage. "We want an unfair fight."

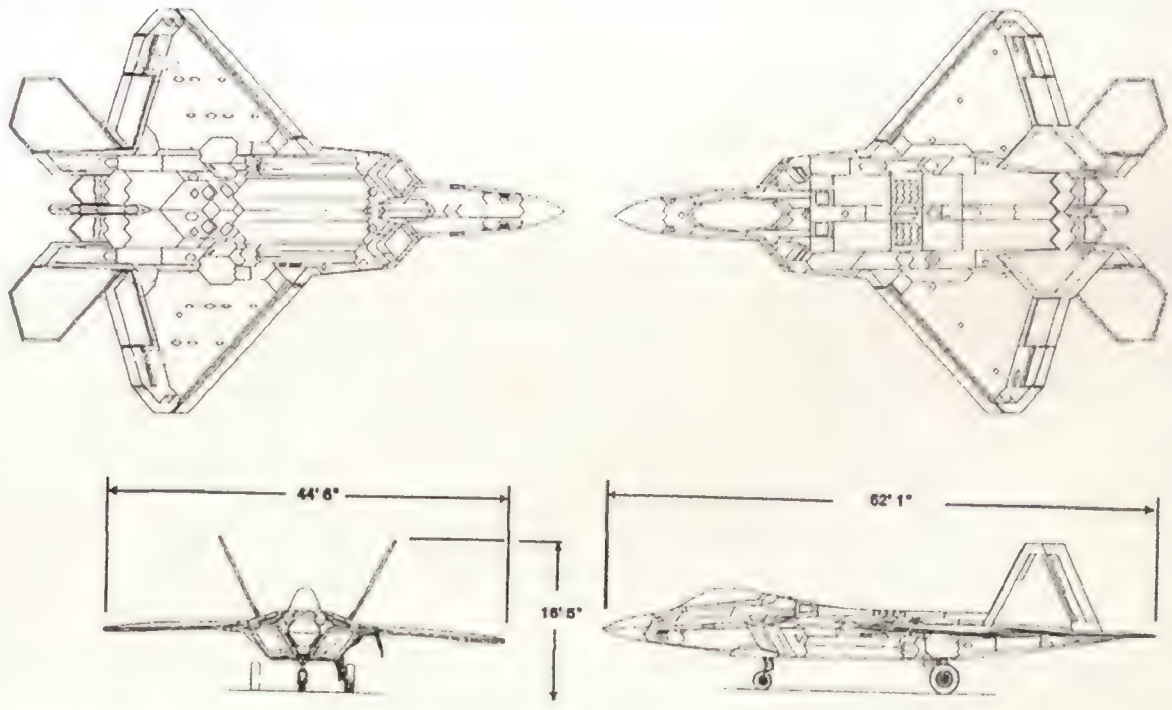
And even if the Air Force's future adversaries are flying older fighters that aren't as advanced as the F-15, such as the MiG-21 and -23, the gap can be narrowed by updating the aircraft to fire modern heat-seeking missiles, which have proved appallingly effective in close-range dogfights. Because missiles are cheap and their design times briefer than those of airplanes, Third World countries tend to have much better missiles than they do aircraft.

There are also next-generation air superiority fighters on the drawing boards of other countries. Russia may be ailing economically, but it is still a nation with a long history of aviation and space achievements. Two next-generation fighters currently under way are the MAPO MFI and the forward-swept-wing Sukhoi S-37. Both aircraft have thrust-vectoring engines, and the S-37 possesses some level of stealth, or low-observability, technology.

With fighter aircraft like these expected to come on line after the turn of the century, the Air Force believes it would be caught flat-footed by relying solely on the F-15 for air superiority. "You can't take an airplane that's already designed and make it a stealthy airplane," says Pruden.

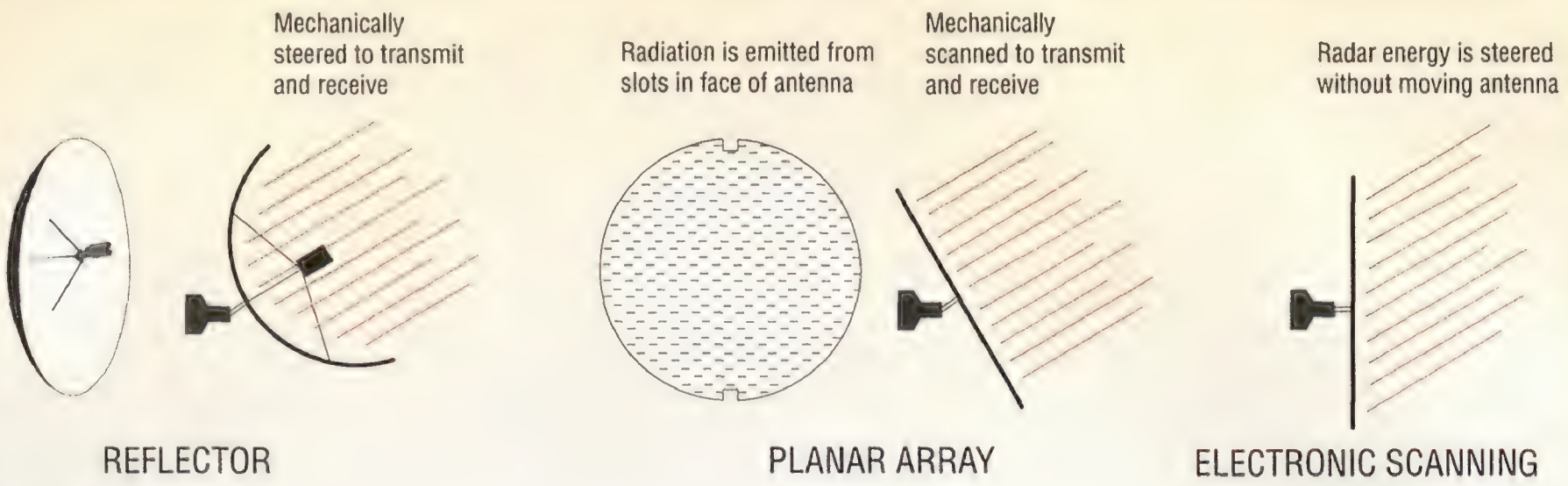
And stealth is the linchpin of first-look, first-shot. A fundamental principle of all types of warfare is that you never want to give up reach. When you close with an opponent, you simply make it easier for your opponent to attack you, not increase your ability to attack him. Of the F-22's stealth, Paul Metz says: "I think that's probably the high card of the airplane. To enter battle and not be seen—it's like the Klingon cloaking device."

Though the F-22 is being billed as an air superiority fighter, it's actually being groomed for air dominance. What's the difference? With air superiority, one side is able to execute all of the air missions that it chooses to against an opponent, but it fights with the expectation of taking some losses, ranging from light to heavy. During the Battle of Britain, for example, the Royal Air Force had air superiority. The British sustained heavy losses, but they were able



Raptor Under Wraps

To achieve a low radar cross-section for the F-22 on a stealth mission, designers eliminated the highly reflective external fuel tanks, stored weapons internally, selectively coated edges, cavities, and surface discontinuities with a radar-absorbent material, and used a sawtooth pattern on seams.



Radar Evolution

One of the simplest radar antennas is the parabolic reflector. The next key advance was the planar array, a much more capable design that consists of many radiators arranged to operate through apertures in a flat surface, but that still steers the beam mechanically. Then came electronic scanning radars, which, by shifting the phase of the signal, can electronically steer the beam without moving the antenna. Such radars can instantaneously direct beams of radar energy of differing widths over a wide area. The antenna of the F-22's AN/APG-77 radar is actually a collection of small transmitter/receivers called an active array that extends the capability even further and allows brief and precisely targeted radar pulses that are very difficult to detect.

to win the conflict and save their country from Germany's advances.

Air dominance is what coalition forces had during the Gulf war: one side completely prevented the other from making any tactical use of airspace. In this case, a large portion of the Iraqi air force was destroyed while parked in hangars, and any Iraqi pilot who tried an offensive move against the coalition was immediately shot down. Other Iraqi pilots took the remaining aircraft and fled into neighboring Iran. Without air dominance, coalition forces would still have won the war, but the casualties would have been much higher if, for example, the Iraqis had been able to use their helicopter gunships to attack ground troops, or if they had been able to use some of their fighters to launch antiship missiles at the U.S. Navy fleet positioned off the coast.

Given a taste of air dominance in the Gulf, the Air Force wants it for future wars. "What we have to recognize is that warfare is not a sporting match," says Hallion. "You're not trying to win 51 to 49. You are trying to utterly dominate and overwhelm the opponent because it is the most merciful thing to do. It brings the conflict to a quick close."

The Gulf war also confirmed the importance of what might be called "data war." Like most modern militaries, the Air Force believes it to be the future of warfare, without which any but guerrilla wars will be lost. Data war means several things. First, it means denying the enemy information, by using stealth, jamming, and attacks on command-and-control sites. If the enemy doesn't know where you are or what you are doing and can't communicate with his forces, he will probably lose the war.

Second, it means distributing to friendly units, via a vast battlefield intranet, all useful information. For example, airborne warning and control system (AWACS) radar aircraft automatically pass data, via computerized data links, to combat craft, telling them where enemy aircraft are, what kind they are, and what they are doing. The joint-service surveillance target attack radar system (JSTARS), a radar ground-reconnaissance aircraft that does for ground forces what AWACS does for aircraft, not only lets commanders on the ground know where the enemy is but also directs offensive aircraft to attack them. The battlefield intranet is still taking shape, but the Pentagon sees it as decisive, and the F-22 was carefully designed to fit into the net.

If you walk around the F-22 Raptor in its hangar in Marietta, it looks like a standard fighter of the modern double-tailed variety—gray, a bit squatty, two engines. It's almost exactly the same size as the F-15 it replaces: 62 feet long, 44.5 feet in wingspan, and having an empty weight of just under 32,000 pounds.

Look more carefully and its stealthy differences appear.

Take the engine air intakes. No engines are in sight. Engine faces are a major source of radar reflection, so the F-22 routes incoming air up over a nonreflecting hump and back down to the engines. Look for armament. You will see none. All eight air-to-air missiles are carried internally to shield their highly reflective surfaces from enemy radar. (This is why the F-22 looks slightly chubby.) When the Raptor fires a missile, powerful hydraulics snap the doors open, kick the missile out, and snap the doors shut to minimize radar returns.

Walk to the tail. The Raptor has 20-degree up-and-down thrust-vectoring engine exhaust nozzles. These aid in maneuvering, increasing the roll rate by 50 percent, but their main purpose is to decrease observability by both radar and infrared detectors.

The twin tails are angled to reflect radar away from an enemy receiver. Radar-absorbent coatings cover parts of the aircraft. The radome on the nose looks like any other, but it is a band-

JOHN ROSSINO/LOCKHEED MARTIN

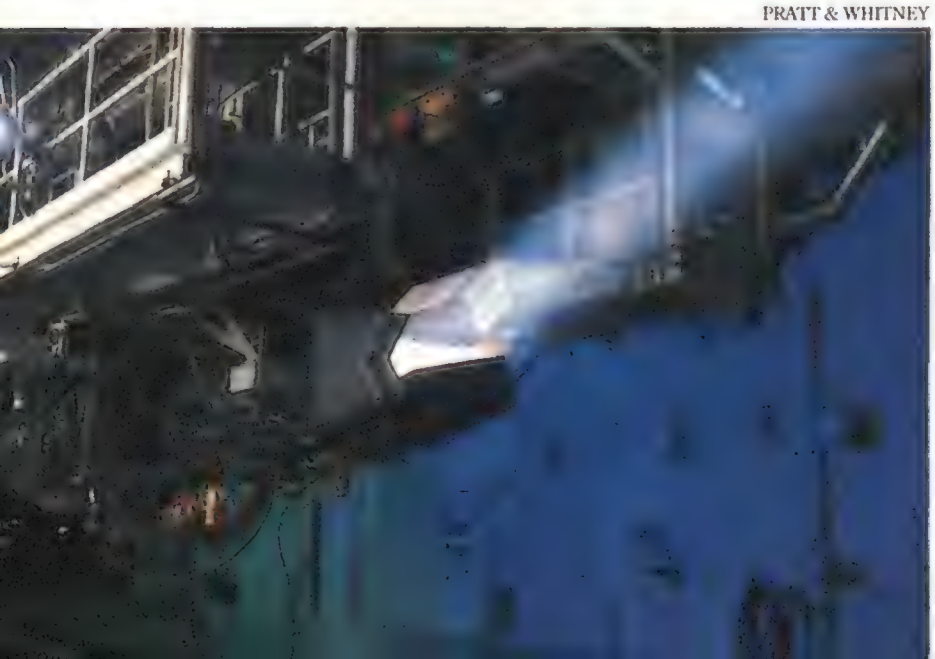
An F-22 on the assembly line at Marietta, Georgia, is draped with rubber sheets to keep workers from scuffing its composite surfaces. Other parts of the airframe are constructed of aluminum and titanium. Thrust-vectoring engine nozzles (below), which are fully integrated with the F-22's flight controls, move up or down 20 degrees, increasing agility and reducing the aircraft's infrared signature.

pass design, allowing passage of only those frequencies used by the F-22's radar. Joints are precisely machined, lines of surfaces exactly parallel. You barely notice the transparent yellow-tinted metallic coating covering the canopy. (The pilot's helmet was a major component in the fighter's radar return, making the coating necessary.)

Just how stealthy is the F-22? Getting a straight answer is difficult. Anyone who knows has a security clearance and can't talk. Burbage describes the aircraft as "virtually undetectable," but there are indications that it is at least a little detectable. It carries chaff and flares, for example, which could help protect it against radar- and infrared-guided missiles. "These measures are there to round out the total defensive suite of the airplane," says Al Pruden. Other defensive goodies include a 20-mm Gatling gun embedded near the right wing root and lots of computer-regulated maneuverability—should the Raptor ever find itself in a dogfight. The F-22's computers will prevent the pilot from overstressing the aircraft during hard turns and direct the control surfaces so that, as one engineer put it, the pilot tells the airplane where he wants to go and the computer figures out how to get it there. "We worked extremely hard to make the airplane very forgiving," says test pilot Paul Metz, "so that the pilot can do anything at any time and not hurt the airplane."

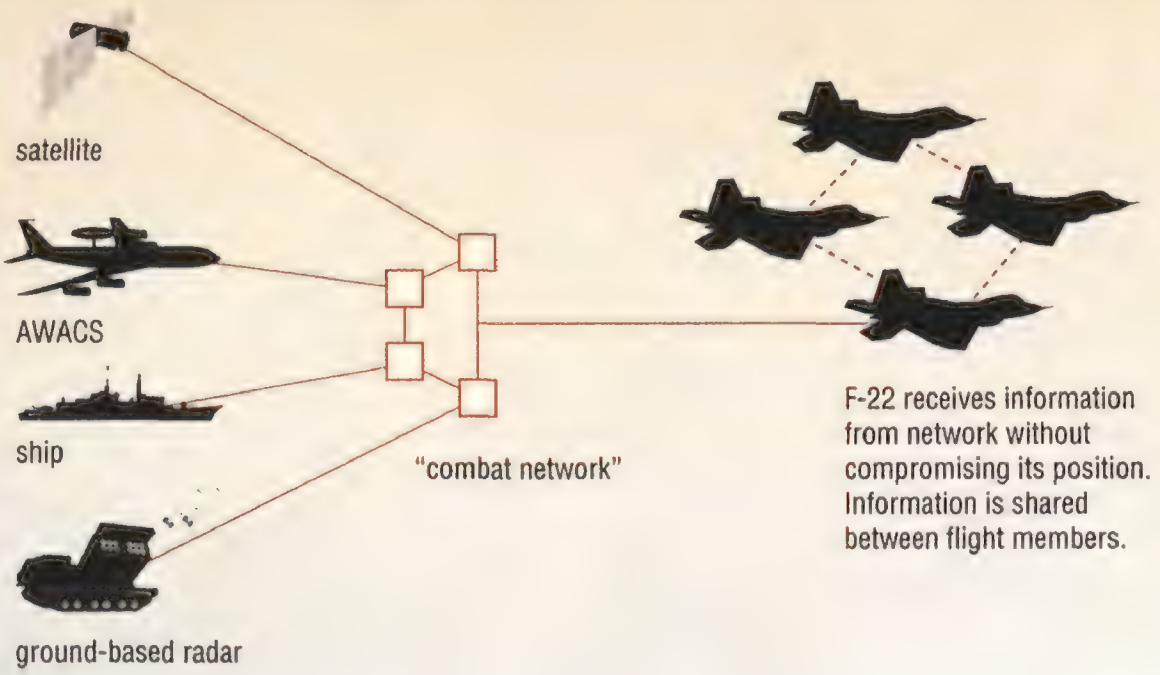
In an engineering sense, stealth wasn't free. A problem the company encountered early on was that the qualities desired for the F-22—stealth, sustained supersonic speed, and dogfighting maneuverability—worked against each other. Supersonic speed favored a thin aircraft with small wings, stealth favored a fat fuselage for internal carriage of weapons, and dogfighting required large wings to grab the air for tight turns. Careful design was part of the answer. Raw power was the rest.

PRATT & WHITNEY



The engines are two Pratt & Whitney F119-PW-100 turbofans, which Lockheed describes as being in the 35,000-pound-thrust class in afterburner. This is enormous power. "One thing that is going to bedevil the Air Combat Command pilot is how easily [the F-22] goes supersonic," says Metz. "It loves to go fast. You've got to keep your throttle back." Yet the 35,000-pound figure is, except in dogfighting, largely irrelevant. The crucial, and classified, figure is thrust without afterburner, as this permits supersonic cruise, or supercruise.

In afterburner, engines dump fuel into the exhaust stream to increase thrust. This works, but at the cost of such high fuel consumption that it can be sustained for only a few minutes, and current fighters usually aren't very maneuverable when supersonic. Further, engines in afterburner are more detectable. "While it was clear to us that the evolution of tactics required sustained supersonic speed, we wanted it without afterburner," says Hawley. "When you use afterburner, all it does is turn you into a heat magnet and you suck up IR [infrared] missiles."



Bogey dot com

The F-22 can receive information from a "combat network" made up of a variety of sources, including airborne warning and control system (AWACS) aircraft, satellites, ships, and ground-based radar. But despite the volume of information exchanged, the F-22's avionics systems don't compromise the stealthiness of the airframe itself. Once data is received by one F-22, it can be linked to other Raptors in the same flight without the use of voice communications.

Supercruise is not speed for speed's sake. It gives the pilot the choice of fighting or retreating. Perhaps more important, supercruise in combination with stealth gives enemy surface-to-air-missile sites little reaction time and forces the missile into a long tail chase, during which it is likely to run out of energy. If the missile is guided from the ground, it will lose the F-22 once the aircraft passes the detection range of the guidance radar. Stealth aircraft impose heavy burdens on an enemy's economy: If stealth reduces detection range to a quarter, four times as many expensive missile sites are needed to form a barrier. Further, airborne interception of an airplane that cruises far faster than you and is nearly invisible is extremely difficult.

But it is the Raptor's avionics that tie supercruise and stealth together into what, if it works as well as expected, will be a new, deadly, and tactics-altering package.

The electronics, like the rest of the airplane, are "low observable," designed with the intention of keeping the enemy ignorant of the Raptor's presence. "Why would a stealthy airplane want to give away its position by radiating?" asks program manager Burbage. He is referring to the fact that when a pilot turns on his radio or activates his radar, he lights up the aircraft with electromagnetic radiation, making himself detectable to the enemy's sensors.

Accordingly, the F-22's radar was designed for low observability. It uses an electronic scanning, active array antenna with no moving parts, consisting of more than 1,500 tiny transmitter-receivers in the nose. This means that, unlike many other fighters, which use mechanically scanned antennas, the F-22's radar can squirt a narrow beam in any direction at any time. No pattern develops for the enemy to notice. If an enemy is too distant to be of immediate concern, the radar will glance at him only occasionally, to keep an eye on him. The radar is also frequency-agile, meaning that it can transmit each squirt on a different frequency. The combination of unpredictable frequency and unpredictable scan makes it difficult for electronically unsophisticated enemies even to know they are being watched. To increase the difficulty of detection, the software can automatically reduce the power output of the radar to the minimum needed to watch the target.

But even a stealthy radar is more of a giveaway than the engineers wanted. Consequently the F-22 can receive tracking and other data from off-platform sources, which means that often it won't have to use its radar at all. "We'd rather fly with the radar in standby, use it only as a passive sensor, and use information fed into the net from such sources as other airplanes, AWACS, the airborne laser, which will be out about that time, ground-based radars, Patriot missile batteries, and Aegis cruisers," says Hawley. "We'd much rather use their information than turn on our radar. But if we're out there autonomously, probably one member of the flight will radiate and the others will share the information. The shooter is likely to be a passive airplane and therefore undetectable to the target."

Even inter-plane communication is stealthy. There is, for example, the intraflight data link, which automatically transmits tactical data between F-22s in the same flight. The link between aircraft is made possible by low-power, highly directional transmitters, running on a frequency that doesn't travel very far before being absorbed by the atmosphere. This means that one Raptor can use its radar and all the others, perhaps miles to one side, will have on their screens the same information seen by the transmitting fighter. The enemy may know there is a Raptor somewhere, but he won't know how many, or where, or what the others are doing.

To see how the F-22 will fight, one needs to understand the cockpit displays. In previous fighters, even comparatively modern ones, electronic systems tended to have their own displays, gauges, and controls. "Too often the pilot became a systems manager instead of flying the airplane," says Lockheed Martin avionics specialist Marty Broadwell. "This time, we show him what he needs to know and nothing else. Now he can concentrate on being a pilot."

To this end, the displays employ what is known in the jargon as "sensor fusion." The Raptor's computers (two common integrated processors, which are modular computers about the size of microwave ovens in the forward fuselage) merge all of the data from different sensors and display it on three full-color, liquid-crystal screens. The center screen provides a "God's-eye" view in which the F-22 is in the center and everything around it—front, back, sides—appears in its correct position. To the left and right, smaller screens provide offensive and defensive information.

There is also a head-up display, or HUD, which projects information on a glass plate in front of the pilot.

Enemy aircraft appear as red triangles, friendlies as green circles, unknowns as yellow squares, and other F-22s as blue circles. Surface-to-air-missile sites are pentagons labeled with the missile's type and range. An airplane's bearing is indicated by a tail growing from the symbol, the length of which gives an approximation of the craft's speed.

The pilot sees, for example, that a MiG-25 Foxbat is on a bearing of 270 degrees at a range of 25 miles and a speed of 450 knots. Because of sensor fusion, he doesn't know where the information came from—radar, AWACS, another F-22. He doesn't care.

How does the F-22 know that the aircraft is a Foxbat? Perhaps because an AWACS has identified it, or it may know via non-cooperative target recognition. This is a largely classified method of identifying aircraft types from such things as the radar returns from their engine blades and the electronic characteristics of their radar.

The Raptor's computers next find the Foxbat's characteristics in a database, including the range of a Foxbat radar against an F-22. This is crucial, since the F-22 wants to destroy the enemy before it itself is detected. The red triangle representing the MiG-25 on the pilot's screen projects a red "fan" showing the range within which the MiG will be able to detect the F-22. (In the case of surface-to-air-missile sites, a red circle shows the detection range. If the circles of two sites don't overlap, the pilot will be able to weave through them undetected.)

Again, stealthy airplanes are not invisible. They are detectable, but only at much shorter ranges than other airplanes. Further, their radar cross-section—their visibility to radar—is different from different angles. The F-22 is designed to be hardest to see head on. If the pilot turns broadside to an enemy radar, the enemy's detection-range "fan" grows toward the F-22 on the display because the avionics system knows how visible the aircraft will be to the enemy at different angles. Thus the pilot not only sees without being seen, but knows when the enemy will become aware of him.

Firing is also simple. If the pilot has several bandits on his screen, he can tell the computer to form a shoot list, in which the avionics decide which targets need to be eliminated first. (He can override it if need be.) The radar (if being used) automatically begins tracking more carefully the targets on the shoot list. An indicator both on the offensive screen and the HUD tells the pilot first when the targets are in range, and then when they are close enough that they cannot escape a missile. He fires. Several missiles, each guided by its own sophisticated fully active radar, race toward the unsuspecting enemy.

It is chillingly simple, more like an industrial process than the high-G, high-adrenaline air combat seen so often in the movies. "It's going to take a bit, I think, of a philosophy change and an attitude change with the F-22, which does its best work when it's simply stealthy," says Paul Metz. "The airplane can certainly turn and burn and maneuver hard. But you want that more as a defensive capability should you ever become uncloaked or should somebody see you."

If everything works as well as Lockheed Martin believes it will—and the Air Force can persuade Congress to continue funding the F-22—the Raptor may have a depressant effect on an enemy's morale. ("I hope so," says Hawley.) Will the F-22 be as effective as hoped? The recent success of American advanced technology weaponry suggests that it will, and other militaries, even U.S. allies, are worried about being left behind. Hawley tells of talking to his counterpart from the United Kingdom: "He said he hoped that we wouldn't find ourselves a few years down the road with the only role the allies could play being to guard prisoners."

As Bob Monsell, the armament integrator for the F-22, puts it: "We figure there are two types of airplanes in the world—F-22s and targets." What airplane could keep pace with the Raptor? Probably only another Raptor.

The YF-22 successfully fired an unarmed missile during prototype testing. If all goes well in the next four years of development, the Raptor should have no trouble taking the first shot in aerial battles of the next century.

VIA AIR FORCE MAGAZINE

COMMENTARY:

Thinking Big

Earlier this year, astronomers announced stunning findings: Observations made by the Hubble Space Telescope and the world's largest ground-based telescopes imply that empty space teems with energy, that the universe has expanded more slowly in past eras and more rapidly in recent ones than astronomers had believed, and that this expansion will almost certainly continue forever.

What do such sweeping pronouncements mean to people reading about them in the newspaper? Certainly the scale of the universe is far removed from the miles or minutes by which most people measure the world. Yet as a professional astronomer and writer for the past three decades, I have found cosmology—the study of the universe as a whole—to touch the human spirit in areas not ordinarily accessible through science. Whispering the secrets of our creation, cosmology speaks to our desires to connect with the vast and complex universe that brought us into being.

So does this year's news from the cosmological front tell us anything about ourselves at levels beyond the rational? Let's begin by examining how astronomers come to know what they do about the nature and fate of the universe.

Seven decades ago, Edwin Hubble discovered that almost all galaxies are moving away from our own Milky Way, with the more distant galaxies receding more rapidly. If we adopt the reasonable hypothesis that we have a representative view of the universe, then all galaxies are receding from one another everywhere: The entire universe is expanding.

Building on Hubble's work, astronomers have concluded that the expansion began about 12 billion years ago, at the moment of the Big Bang. To reach this conclusion, astronomers combined their observations of galaxies' motions—which they determine by measuring changes in the color of the galaxies' starlight—with measurements of the galaxies' distances from our own.

The latter task proves much more daunting. To reveal the distances to galaxies millions or billions of light-years away, astronomers seek to find standard candles, luminous objects that have nearly identical outputs of energy. Once a collection of standard candles is recognized, astronomers can determine the relative distances to each member of the group, because they well know how the differing distances affect the objects' apparent brightnesses: One standard candle seen at twice the distance of another will have one-fourth its apparent brightness. As their observational abilities have improved, astronomers have looked farther and more accurately backward in time, studying objects so far from us that their light, speeding at six trillion miles per year, has taken billions of years to reach the Milky Way.

During the past few years, astronomers have found excellent standard candles within a category of exploding stars called Type Ia supernovae. Type Ia's end their lives with a fiery outburst, shining for a few weeks with more luminosity than a billion ordinary stars. Astronomers have uncovered a way to discern subtle differences among these supernovae, assigning each Type Ia to a subgroup in which all members reach the same maximum energy output. Each subgroup is recognizable out to distances of billions of light-years. When astronomers observe a Type Ia supernova in any galaxy, therefore, they now know how far away its host galaxy is.

This year's big news (independently announced by two international teams of astronomers and astrophysicists, one led by Brian Schmidt of the Mount Stromlo and Siding Spring Observatory in Australia, the other by Saul Permutter of the Lawrence Berkeley National Laboratory) is this: The Type Ia supernovae observed in galaxies billions of light-years away turn out to be

DAVID POVILAITIS

Donald Goldsmith explains why the idea of being at one with the universe may be more than a New Age cliché.

significantly farther away from the Milky Way than conventional models of the expanding universe had predicted. This apparently means that although the expansion of the universe has slowed down during most of the time that the galaxies' light has been traveling to reach us (just as astronomers would expect from the mutual gravitational attraction among all the matter in the cosmos), the period of slowing has stopped and the expansion is now accelerating.

To explain this, astronomers conclude—not definitively, but with a degree of acceptance to be tested by further observations—that space itself must be loaded with energy. This energy is giving the entire universe a continuing shove, the effects of which will become steadily more noticeable in future epochs.

Cosmologists describe the energy of empty space in terms of a "cosmological constant"—essentially an anti-gravity force, a concept introduced by Albert Einstein. Einstein believed the universe was static and invented the cosmological constant as a "fudge factor" in his equations describing the universe, allowing it to exist without either expanding or contracting. Following Hubble's discovery that the universe is indeed expanding, Einstein called the cosmological constant his "greatest blunder." But the cosmological constant now seems to be no blunder at all.

The news of its apparent existence carries an important consequence, far more direct than a simple increase in our wonder and awe, because it suggests a relationship between ourselves and the universe. Cosmologists have previously produced arguments based on accepted theory that the cosmological constant ought to have one of two values: zero, or a number so large that the universe would expand too fast for galaxies, stars, planets, or people to exist. The recent results suggesting the existence of a cosmological constant with a small value cannot be explained by our current theories—unless we assume that our universe is but one of a plurality of universes in a "meta-universe," each with its own value of the cosmological constant. If so, the most likely values of the constant could still appear in abundance, along with fewer less likely values.

One explanation for the extremely unlikely value of "our" cosmological constant is that we observe that value precisely because we exist to observe it. In other words, because the majority of the other universes, with their different cosmological constants, provide no chance for anything like ourselves to evolve, we naturally find ourselves in the universe characterized by one of the remarkable, odd values of the cosmological constant required for life to flourish for billions of years.

> New results suggest we may be crucial to the explanation of why the universe is the way it is.

Cosmologists call this explanation of why we live in an "abnormal" universe the anthropic principle. Most scientists are leery of it, mainly because it violates a fundamental tenet of science: the separation of the observer from the observed. Scientists also resist a theory that makes humanity, or at least the totality of life on Earth, essential in explaining why we find the universe with the set of characteristics it actually possesses rather than the set that our best understanding tells us is more likely to occur.

On the other hand, some cosmologists, and many ordinary people, feel that the anthropic principle provides a wonderful, visible link between the cosmos and our existence. The fact that the new results suggest we may be crucial to the explanation of why the universe is the way it is, and imply the existence of a much larger meta-universe outside our own, only makes the results more marvelous.

My feelings lie with the larger group of cosmologists, but I delight in the anthropic principle's ability to raise our collective cosmic consciousness. Furthermore, my opinion about the anthropic principle does not resolve the issue of its validity. (I never tire of inserting this modest truism.)

The supernova observations suggesting that the universe in which we live has a non-zero cosmological constant have reawakened the debate about our role in the cosmos. I find this fact as exciting as the scientific results themselves: It implies that science has more to tell us about the meaning of life. Even better, if the anthropic principle should prove valid, it would elevate not individuals, arguably not even humanity as a whole, but the existence of any form of life capable of observing the universe. Thus life could be the explanation of why the universe—our universe—is as it is.

Will 1998 mark a new stage for humanity, not only in our scientific understanding of the universe but also in our spiritual approach to it? I rather doubt it, to be honest. But the fact that these findings allow me at least to seriously pose the question makes my heart beat a little faster.

The author has written 15 books on astronomy. His next book, *Q-Zero: The Race to Find the Future of the Universe*, will be published in 1999 by Helix Books.

The Wizards of What If

Though asteroids star in two summer movies, science plays a supporting role.

by George C. Larson

Hollywood has brought us towering infernos in high rise buildings, titanic ships that sink to the bottom of the sea, and volcanoes that erupt in downtown Los Angeles. But these are mere irritations compared to the disaster envisioned in a movie from Disney's Touchstone Pictures opening in July. In *Armageddon*, audiences will see a terrifying yet plausible vision of life on Earth threatened with total extinction.

The instrument of death and destruction is an asteroid that has been split off from a larger orbiting body and sent on a freakish collision course with Earth. We Earthlings have roughly 18 days to form our various blue-ribbon committees, task forces, and legislation to rid our skies of this menace. Just kidding: In the film, it's panic time.

PHOTOS BY FRANK MASI ©TOUCHSTONE PICTURES AND JERRY BRUCKHEIMER, INC.

What makes *Armageddon* (and an earlier DreamWorks feature with a virtually identical premise, entitled *Deep Impact*) so compelling is the knowledge that Earth has been hit by large objects in the past, and, scientists tell us, will be hit again. As if to reinforce this, a brief scare in mid-March of this year predicted that our lovely blue Earth was due to be kissed on the lips by a big ugly rock about a mile in diameter in the year 2038. This terrifying prospect was canceled (some would say only postponed) mere hours later when further calculations showed that the thing would miss us by 600,000 miles. But the point had been made, and not that long after the images of the Shoemaker-Levy 9 comet hitting Jupiter's atmosphere had begun to fade in our collective memory. (You remember Shoemaker-Levy: The comet's fragments exploded like H-bombs and left huge scars in the Jovian atmosphere. Very spectacular. Very unsettling.)

The producers, writers, and directors of *Armageddon* and *Deep Impact* have borrowed a few ideas from these real-life scenarios to make space movies that are a little different from the usual box office offering. Unlike such fantasies as *Star Wars* or the *Star Trek* series, in which imagination rules, the asteroid disaster genre strives for reality in its concept and special effects. (No live-action film from Disney has ever had a bigger budget.) And to make their productions as believable as possible, the filmmakers turned to a corps of technical advisors recruited from the ranks of NASA.

Gerry Griffin, a former director of NASA's Lyndon B. Johnson Space Center in Houston, Texas, advised the makers of *Deep Impact*, from the shaping of the script to staying, in his words, "glued to their hip" during shooting. "They ask me to look it over so it looks right and sounds right," he says. "I spent fully a third of my time in script tuning. There are a few times when we take out a clean sheet of paper, but more often it's a matter of tuning the script to make it realistic."

He also hunkered down with the actors, including Robert Duvall, who plays a veteran astronaut. "I went to Virginia and spent time at his farm," Griffin says. "[Former astronaut] Dave Walker was with me, and we sat with him the better part of two days and went through all his parts of the script. Actors don't want to look dumb or stupid. They want to check out how to do something, and they have minds like sponges. They want to learn what real people do." The most difficult thing to imagine, Griffin says, is what it's like to be weightless. Duvall wasn't weightless during the making of the film, but he learned how to fake it courtesy of Griffin and Walker (see also Flights & Fancy, p. 22).

Unlike Griffin, who had previous films under his belt (*Contact* and *Apollo 13*), Joe Allen, the chairman of the Calspan SRL Corporation, had been only a moviegoer before his work with *Armageddon*. The experience Allen offered was that of a physicist and former astronaut: He knows what it's really like in a spacecraft. "In the initial script, they had the shuttle crew addressing one another rather formally—'Dr.' this and 'Commander' that," says Allen. "But the attitude on board is always much

Armageddon's killer asteroid is a mean chunk of stuff on which spacesuited visitors must exercise extreme caution. Unintimidated, Harry Stamper (Bruce Willis) and a band of oilfield roughnecks (right) try to steer it clear of Earth.

more informal, not that strict military-style respect for authority. I kept harping on that, and the actors themselves were not a hard sell. They picked right up on it."

Both Griffin and Allen accepted the filmmakers' occasional need to compromise scientific fact for dramatic effect, and they freely admit that not all of their advice was heeded. For one thing, photos of actual asteroids such as Gaspra, which was snapped by the spacecraft Galileo, revealed a big rock that's about as threatening looking as a sweet potato. To director Michael Bay, who comes to Hollywood with credentials as a maker of music videos, a big spud is just not good enough. To create the set representing the surface on which the astronauts would land and drill, he first removed the floor from the largest sound stage at Disney studios, excavated 20 feet down into the soil beneath the building ("We wondered for weeks where all those trucks were getting that dirt they were carting off," said one stagehand on the Disney lot), then constructed enormous, jagged, crystalline outcroppings with steam lines venting great clouds of vapor. To Allen that was a "reach," certainly, but not implausible. "If it was, in fact, freshly broken from a larger body after an impact, the surface might well be violent and energetic," he says.

On point after point, Allen credits the *Armageddon* script with scientific integrity. To reach an inbound asteroid by flying up to it aboard a shuttle-like craft, for example, the spacecraft would have to first attain a high velocity outbound from Earth, then turn around and rendezvous with the collision-bound body. "This is a huge delta V [change in velocity vector]," Allen says, and in real terms, "there is a finesse around that using a crack-the-whip maneuver using the gravity of another body—in this film, the moon—to turn you around. Of course, the chance that the moon would be in just the right spot in all of the four pi [the sky's spherical area] of space is a stroke of pretty good luck."

Scenes from the movie, counterclockwise, from top left: As bits of asteroid fall onto urban centers (causing traffic delays), the novice astronauts train for a hazardous space mission. Ben Affleck and Liv Tyler provide a romantic subplot for those who want to see something besides Willis and an asteroid go head to head. In a departure from the conventional, a nuclear device is used to save the world.

Even the newer and nastier shuttle Disney conjured for the film was astonishingly realistic. "If we could have put tiles on it, we could have flown it," Allen says.

Simultaneous shuttle launches? No problem. In the film, two shuttles launch together and fly to their target in formation. "I don't think that would be a great stretch of the imagination at all," Allen says. "We have two launch pads and there are backups for the firing rooms, so if you think about it, this [doomsday] is all or nothing. You're betting *everything*, so there's no backup. You have two [shuttles] so you launch 'em all."

In the story, a team of oilfield roughnecks led by a character played by Bruce Willis is sent to the asteroid's surface to save Earth by drilling into the inbound body and cleaving it along a known fault line with a nuclear bomb. With only 18 days to achieve success, their 12 days of training is...well, an abridged version of reality. "This was interesting to me

A film crew makes the super shuttle merely appear to fly (below), but experts say the craft looks real. Once on the asteroid, the astronauts drill into the surface with an imaginatively muscular off-road vehicle equipped with a ferocious drill bit (bottom).

from a NASA point of view," Allen says. "Three-quarters of an astronaut's training is spent on learning emergency procedures, but in this scenario, it's all or nothing, so they spend absolutely no time on that. You get rid of most training [for the drilling crew] and send the most experienced crew you've got to do the flying."

The filmmakers' penchant for realism may owe something to its producer, Jerry Bruckheimer, whose past credits include *Top Gun*, a classic depiction of naval aviation fighter weapons school and perhaps the most popular flying film of all time. "Whatever arena we're in, we find an expert," says Bruckheimer. "Joe read the script a number of times, gave us notes and comments. We did a tour of [Johnson Space Center in] Houston, and during the time we were at NASA and on every NASA set, he related technical direction to the actors. He had the shuttle experience, from countdown to launch, and, in fact, he did the actual countdown in the film. [Former NASA manager] Ivan [Bekey] told us what *could* happen with the asteroid. He did the math, calculated the moon passage and all the velocities. He told us the various ways they would deal with it."

While *Armageddon* gets high marks for accuracy, it isn't perfect. Allen points out that there is an "uncoupling from reality" (he *is* a physicist, after all) in the sequence in which the explosive is planted after the asteroid has already passed the moon on its way to Earth. This leaves something less than three days' time before the asteroid hits, and, Allen points out, it would take an enormous amount of energy to split a Texas-size chunk in two and push the halves apart with enough force that they would clear the 8,000-mile-diameter Earth in the time allowed. The bomb in the film has enough power to split the asteroid, Allen says, but it wouldn't shove the halves apart that fast.

But hey, it's a movie—one that, despite the occasional conflict between truth and beauty, could have its own impact (sorry) on the real world. If enough people come away moved by what they have seen in *Armageddon* and *Deep Impact*, the tiny band of believers who want NASA and other agencies to plan for the inevitable could grow. The Harvard-Smithsonian Observatory's Minor Planet Center has created a catalog of 112 Potentially Hazardous Asteroids, or PHAs, that cross Earth's orbit on a schedule as precise as so many German trains. (For a timetable of close approaches, visit their Web site at http://cfa-www.harvard.edu/iau/lists/Dangerous.html.) If astronomers do spot a big one on its way toward us, we now have people in Hollywood who have thought—creatively—about ways to head it off.

A Sudden Loss of Altitude

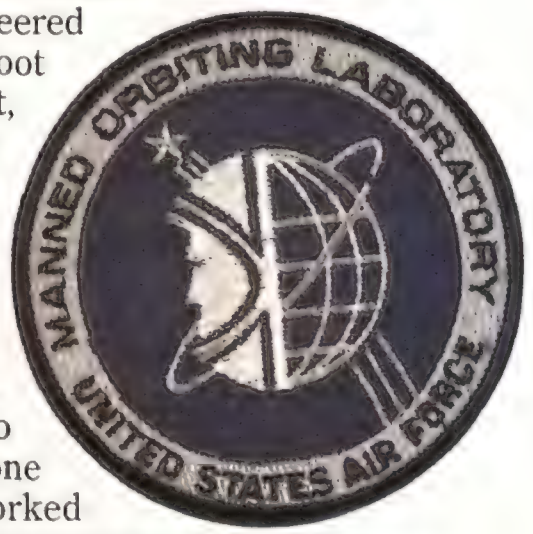
The Manned Orbiting Laboratory would have been the world's first space station. But as the best military pilots were training for duty 150 miles up, the MOL program shut down.

The moment, when it finally arrived, was bittersweet—bitter for having taken three decades to complete the journey of an afternoon, sweet to have a broken circle closed at last. December 8, 1997, marked the 30th anniversary of a crash at California's Edwards Air Force Base in which 32-year-old Major Robert H. Lawrence Jr. was killed. Most accounts refer to the crash as a training accident. In the same spirit, one would call an extreme skier's fatal hundred-foot plunge a spill.

On that day in 1967, Lawrence occupied the rear seat of an F-104D Starfighter, with Major Harvey Royer, operations chief at the Aerospace Research Pilot School, in front as pilot in command. The two took off into the pounding clarity of the desert afternoon, climbed to 25,000 feet, and began shooting approaches meant to simulate the return of a spaceplane from orbit. The profile called for a 25-degree dive (the average airliner's glide slope is inclined about three degrees) and an airspeed of 330 mph, with thrust at idle power and landing gear, flaps, and speed brakes all fully extended. The idea was to land a fast-moving machine from which the will to fly had been largely removed.

During one approach, according to the official Air Force summary, "the aircraft contacted the runway left of centerline, approximately 2,200 feet from the approach end. Both main gears collapsed on the runway on first contact, and the canopy shattered. The fuselage dragged on the runway for 214 feet before the aircraft again became airborne. It subsequently touched down at the 4,000 foot mark, veered to the left and departed the runway at the 4,235 foot mark." Its underside blazing from the first impact, the F-104 veered off the runway and began to come apart. Both pilots ejected. Royer, badly injured, survived. Lawrence got out, but his parachute failed to deploy fully.

The two men were preparing for a new era in which pilots—military pilots—would take the high ground of space. Lawrence already was among a small cadre of exceptional fighter pilots training to be the first Air Force astronauts. If things had gone according to plan, they would have lived and worked aboard a space station well before any NASA astronaut or Russian cosmonaut set foot inside a Skylab or Salyut.



by Carl Posey

But Lawrence lost his opportunity to soar beyond the atmosphere—and to be the first African American to go there—that terrible afternoon at Edwards. Thirty years later to the day, the Florida-based Astronauts Memorial Foundation settled a long-running dispute over who exactly should be considered an astronaut and engraved his name on a commemorative mirror bearing the names of fallen space travelers.

The Air Force, though, has never had its own broken circle closed. Its space station, called the Manned Orbiting Laboratory, was suddenly and without much argument canceled in June 1969, without ever getting the chance to prove its utility. The 1960s presumption that by the end of the century the Air Force would have become a space force quickly evaporated, and today, even advocates of an extraterrestrial military presence can only just recall the time when the question was not whether, but how soon.

When the 1960s began, it looked as if wars would have to be fought on every front from seabed to Earth orbit. The cold war had begun to burn hot in Africa and Asia, and a good part of the developing world was dividing along ideological lines. Francis Gary Powers, his U-2 spyplane brought down by a missile in May 1960, was doing 10 years in a Russian prison. By the time he was traded for a Soviet spy in 1962, his erstwhile hosts were thinking about a 75-ton manned space platform that could carry nuclear weapons into low Earth orbit—Battlestar Khrushchev. Indeed, back then it looked as if space might go to the Soviets.

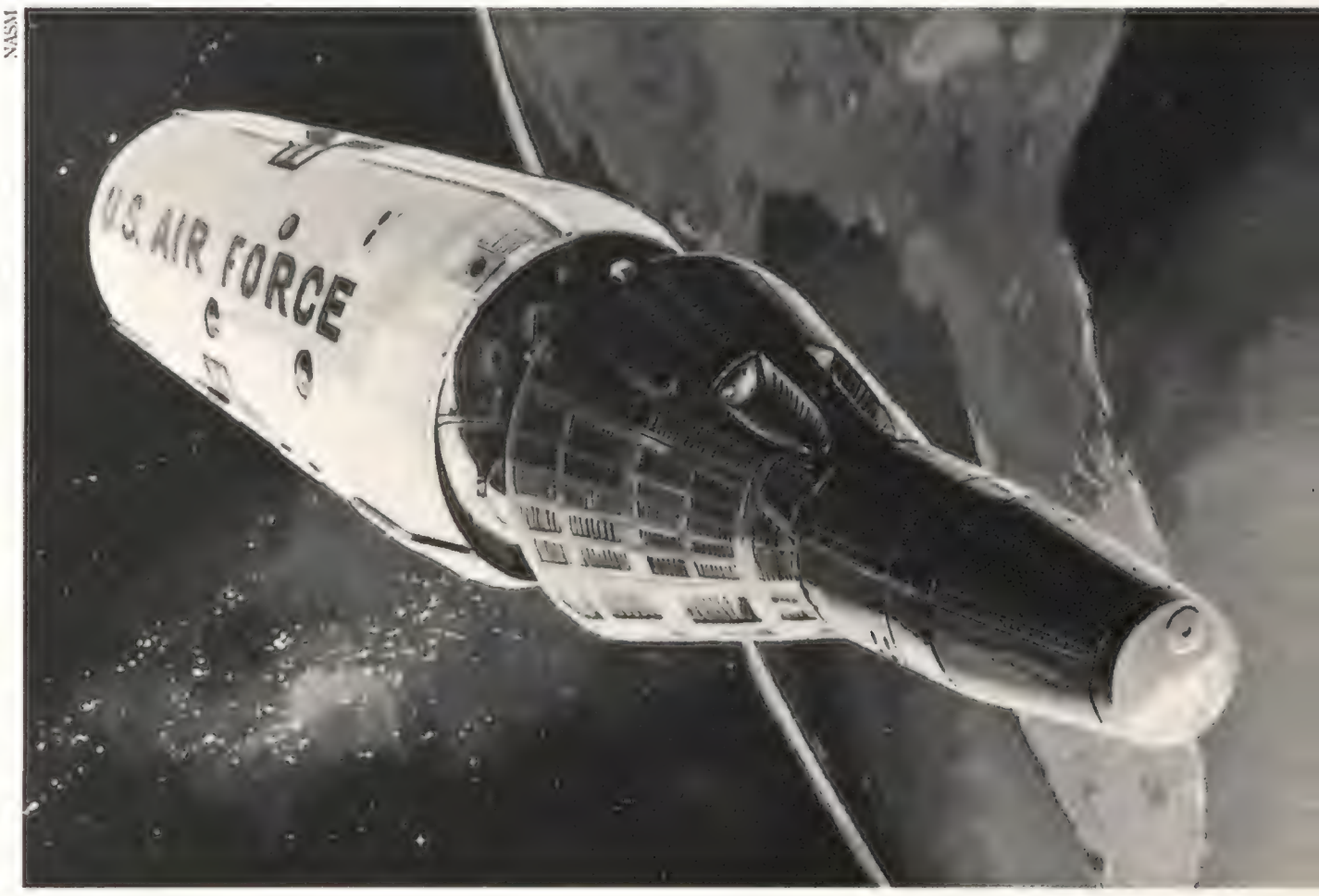
Not to be outgunned, the U.S. Air Force sketched out a 10-year plan in 1961 that assumed battle lines would extend into Earth orbit. As the obvious gatekeeper to the new theater of operations, the Air Force proposed putting a continuous military force into space in the form of piloted craft, manned surveillance platforms, and space stations. It would cost tens of billions of 1960s-vintage dollars, but it might help to prevent that other reasonable expectation of the epoch: thermonuclear war.

The Air Force already had rocketplanes, most notably the X-15, which took pilots to the brink of space. By 1963 Joe Walker had flown an X-15 to an altitude of 67 miles, a record for a winged vehicle that stood until the space shuttle *Columbia* broke it 18 years later.

The next step was to have been a piloted delta-wing craft that could ride into orbit on a Titan booster, maneuver and rendezvous in space, and glide back to Earth much as the shuttle does today. It was seen as an all-purpose spaceship—freighter, scout, fighter, nuclear bomber. With this craft, the Air Force would have an offensive capability in orbit.

Someone, ignoring the Fates, called it Dyna-Soar (from "dynamic soaring") and thus doomed it to extinction. Even with an appetite for delays and design changes, Dyna-Soar might have survived the realities of engineering development. But it had almost no chance of surviving the Department of Defense, whose stern new headmaster was scrutinizing all the upperclassmen's privileges. A vessel such as Dyna-Soar, whose strong suit was exploring operational *terra incognita*, was ill-equipped to parry questions of cost and performance asked by Robert McNamara's Pentagon.

The end, when it came on December 10, 1963, took a curious form. Having found the billion-dollar space glider wanting in the cost/benefit equation, McNamara canceled Dyna-Soar. But, after flunking one bad boy, the headmaster beamed with favor on another. He authorized the Air Force to take a closer look at another of its ideas, a stripped-down space station called the Manned Orbiting Laboratory. There was a catch, though: MOL would fly only if the generals could first define and justify a military mission in space that couldn't be done by NASA.



NASM

Although MOL borrowed ideas and hardware (including a modified Gemini space capsule) from NASA, its reconnaissance mission was strictly classified.

Both the civilian space agency and the defense department had already begun playing with ideas for Earth-orbiting outposts and had signed an agreement only a few months earlier promising that any work on a national space station would be coordinated "to the greatest extent possible." But at the time, Americans had logged only 54 hours in space, and neither the Air Force nor anyone else had a clear idea of what humans could and couldn't do up there.

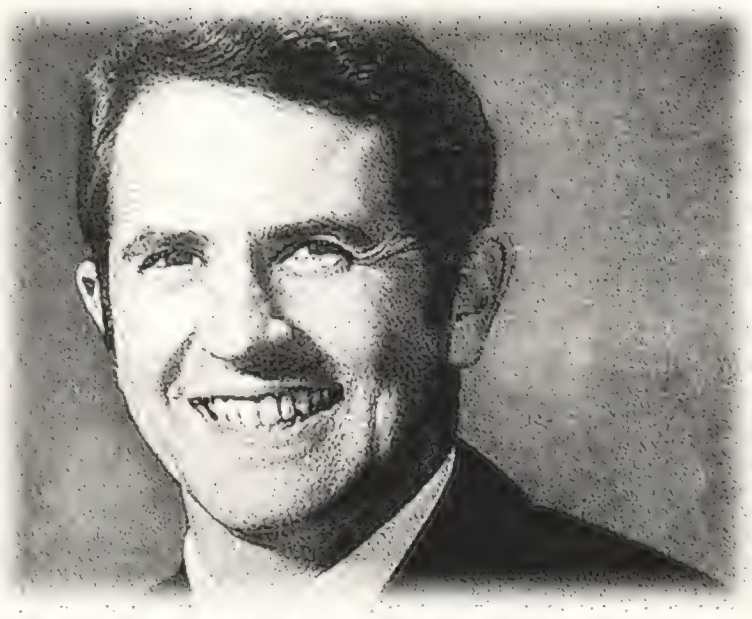
Still, if the Air Force wanted a space program, MOL was now the only game in town. So the service began to pull to-

gether a project. A few basics had already been established: The station would consist of a modified Gemini capsule attached to a cylindrical module 10 feet in diameter and 42 feet long. About half of this volume would be a pressurized working environment for the two-man crew. Another unpressurized section would contain life support equipment, plus a restartable rocket engine for orbital adjustments.

A Titan III would launch the station whole into a 150-mile-high orbit. Once aloft, the two astronauts would leave the Gemini, which rested in the forward end of the lab module like a stopper in an aluminum decanter, and move into their workplace. After a week or two—the maximum duration of a MOL mission was to be about 30 days—the crew would return to the Gemini capsule, separate from the lab module, and orient their little craft, heatshield forward, for reentry, a parachute descent, and recovery at sea. The station was not designed for permanence: Once abandoned, it would be deorbited to burn up in the atmosphere, and a new one would be launched for the next mission.

The Air Force called the station a laboratory, but the work inside was hardly to be pure science. The flights were billed from the beginning as what a *Time* magazine article called "military patrols—watching and photographing activity behind the Iron Curtain, inspecting suspicious satellites and destroying them if desirable. Patrols might carry nuclear weapons for use against the ground or other spacecraft. Some optimists believe that they might even detect hostile nuclear submarines below the surface of the ocean."

The primary experiments proposed for MOL appear to corroborate its reconnaissance mission. At the top of the list were the use of large optics in space, tracking of targets on and off Earth, electromagnetic intelligence surveys, multispectral photography, and post-strike target assessment. MOL would carry the six-foot-diameter KH-10 spy camera (code name Dorian), which could resolve features as small as a softball. In fact, the MOL mission profile bore a powerful resemblance to that of its Russian counterpart, the Salyut military space station, which also was equipped for surveillance and which first flew in 1974.



NASA IMAGES DIGITIZED BY RANDY MAYS (5)

Truly: Went on to head NASA in the early 1990s

The astronauts would also explore the assembly of large structures—for example, the linking of several MOLs into an orbiting complex that eventually would have looked rather like the Russian Mir. They would learn to maintain and repair their craft, do biomedical experiments, and conduct spacewalks with a backpack maneuvering unit (which eventually flew on NASA's Skylab space station in the 1970s).

But today, a polar-orbiting MOL sounds less like a Skylab-type undertaking than the first military outpost in space, a U-2 no Soviet missile could reach, and perhaps something more. That may explain why, 30 years on, those who worked on the project still won't say much about its mission. Lachlan Macleay, who was among the first group of MOL pilots chosen in 1965, says only: "As far as I'm concerned, nothing has been declassified at all. We spent a lot of time in training, let me put it that way."

Dyna-Soar's death in 1963 opened the way for MOL, but squashed the Air Force's plans for an operational spaceplane. Neither vehicle, as it turned out, reached orbit.

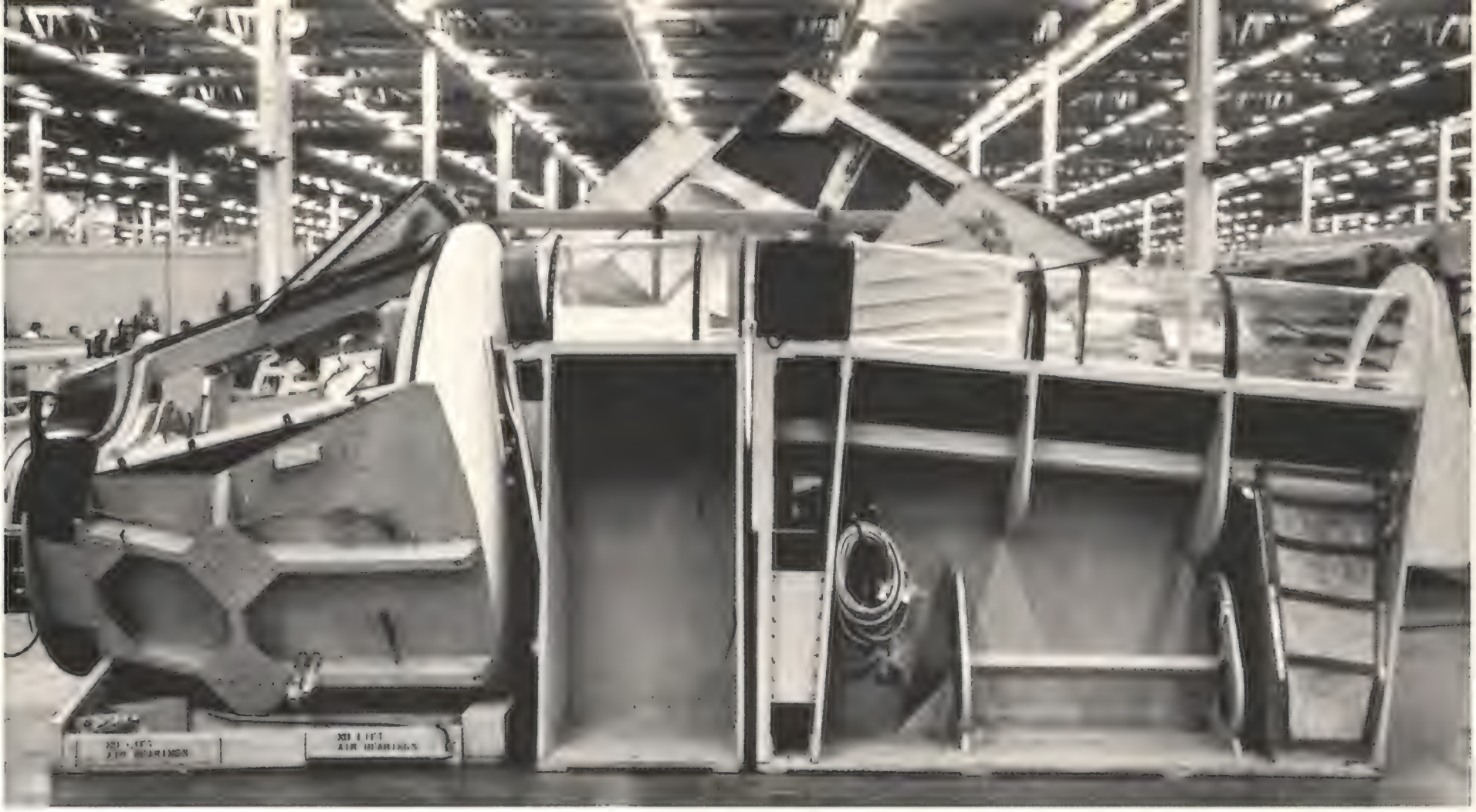
COURTESY ROY HOUCHIN

President Lyndon Johnson gave MOL an official go-ahead in August 1965. Douglas Aircraft would build the laboratory module and McDonnell Aircraft the modified space capsule called Gemini-B. General Electric would manage the onboard experiments. Launches would be from both Cape Kennedy in Florida and Vandenberg Air Force Base in California, which would allow the lab to reach high enough latitudes to fly over the Soviet Union. The first unmanned shot was scheduled for 1968, with the first crew to follow later that year. Within hours of the White House announcement that MOL would go ahead, a dusk of secrecy settled upon the project, and from that point on the public would see only its innocuous exterior.

MOL's advocates in the Air Force must have felt relieved. At last they could begin thinking in terms of hardware and flight testing. And they could begin sorting through the best of their best, looking for space station crews. The first MOL pilots—the title they proudly adopted to differentiate themselves from NASA astronauts—were named in November 1965: Air Force Majors Albert Crews and Michael Adams (who would leave MOL in July 1967 to fly the X-15); Air Force Captains Richard Lawyer, Lachlan Macleay, Gregory Neubeck, and James Taylor; and Navy Lieutenants John Finley and Richard Truly.

Truly, who at the time was enrolled in test pilot school at Edwards, recalls that Chuck Yeager, then head of the school, and his deputy handpicked the MOL crew. "They never even asked me," he says. It was nearly a year between the time the eight were selected and the day their names were made public. The announcement came on Truly's 28th birthday.

The first MOL-men were members of the same fraternity



NASM

MOL pilots practiced floating through this mockup of a transfer tunnel during zero-g aircraft flights.

that produced NASA's early astronauts. "We all knew each other," says Macleay, a former U-2 pilot who had twice been rejected by the space agency for being, at six foot two, too tall. Once selected, the MOL pilots flew the same kinds of simulators that their civilian counterparts flew, endured the same jungle survival courses, and ran into each other during the same frequent trips to McDonnell's Gemini plant in St. Louis.

If any rivalry existed between the two groups, it was defused by the fact that their missions did not overlap. But the contrast between the programs didn't escape the MOL pilots. NASA, recalls Macleay, "had really neat simulators—I mean, even their offices were nice. They were really kind of first class." And while the astronauts were driving Corvettes and appearing on the cover of *Life*, "we were just low-key. Hardly anybody knew we even existed." The original MOL group, with perhaps the slightest edge of mockery, dubbed themselves "The Magnificent Eight."

"It was kind of a source of pride among ourselves," Macleay laughs. "We used to joke that the only news announcement made when we launched would be something like 'The Air Force launched two guys into space today from Vandenberg, and they'll be back in 30 days.' "

In June 1966, five more pilots were named: Air Force Captains Karol Bobko, Gordon Fullerton, and Henry Hartsfield, Navy Lieutenant Robert Crippen, and Marine Captain Robert Overmyer. Fullerton was assigned to Wright Patterson Air Force Base in Ohio when the call came for applications for MOL and NASA. "You indicated which program you wanted, or both," he recalls. "I checked both."

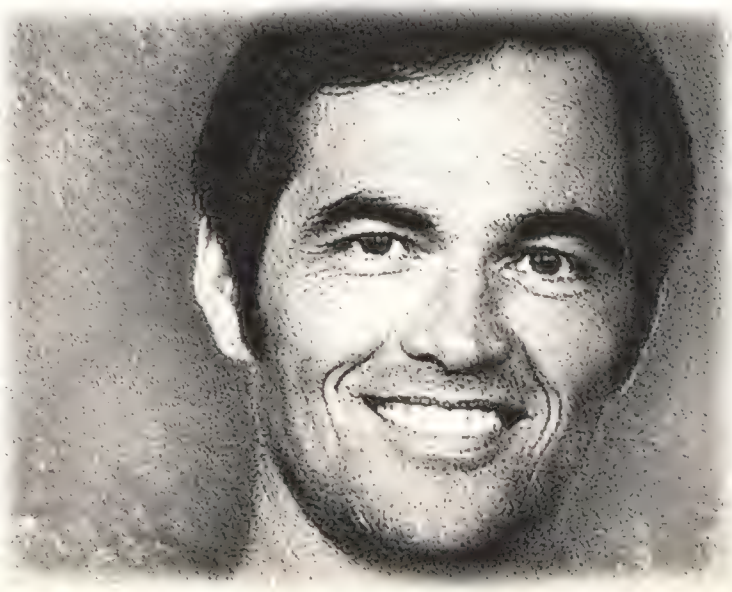
A final foursome—all Air Force officers—was named the following June, having just graduated from test pilot school: Lieutenant Colonel Robert Herres and Majors Robert Lawrence, Donald Peterson, and James Abrahamson.

Training was conducted in two phases, the second of which dealt specifically with MOL. Some of the initial training was generic preparation to become Air Force astronauts, which meant helping to develop and test the odd hybrid vehicles that would eventually take them and their successors into space. MOL pilots flew flight simulators and aircraft rigged (or forced) to behave like spacecraft, including an NF-104A, which was equipped with a 6,000-pound-thrust rocket motor. They flew hair-raising approaches like the one Harvey Royer and Robert Lawrence were attempting when Lawrence died, and they flew high-energy zooms that took them close enough to the rim of the atmosphere that they had to wear pressure suits.

On the academic side, they studied rocket power, mechanics, and the biomedical aspects of spaceflight. And there was always that other, secret side of MOL to learn.

"We had a huge volume of work," recalls Richard Lawyer. "I came from a combat-ready fighter unit and I felt my flying skills were going downhill. But in the second six months, you really felt like you were learning something."

Crippen: Now a top executive at Thiokol



While the crews trained and studied, their orbital station began to evolve slowly from concept to actual hardware. The project borrowed whatever ideas, equipment, and manpower it could from NASA (Congress more than once directed the two agencies not to duplicate efforts) and invented when necessary. McDonnell, for example, had to figure out how to move the crew from the Gemini capsule to the lab module after MOL reached

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The station's spartan living quarters would have had sleeping pods for two, and few other amenities.

orbit. The engineers tried various ideas—spacewalks, an inflatable crew transfer tunnel connecting the Gemini and module hatches, rotating the capsule to stick its nose into the module, like a bee's into a flower, and cutting a 26-inch-diameter circular hatch in the Gemini capsule's heatshield that the crew could float through. The last idea was selected provisionally, pending flight tests to determine whether a hatch in the heatshield would stay sealed during reentry.

The Gemini-B required other changes from the NASA version, which had first carried astronauts into orbit in March 1965. Retro-rockets and other equipment stuffed into a bay behind the shield were modified to accommodate the transfer hatch and MOL's higher orbit. The capsule also had to be capable of restarting after its month-long sleep at the tip of the lab module.

At the time, the MOL lab module was the most spacious of any American spacecraft—about 400 cubic feet per astronaut. The arrangement was simple: two men in a can, with beds at one end, stores at the other, one wall for food and hygiene, one wall for work. Unlike the later Skylab, MOL had no shower. It would have felt roomy ("Zero-G really opens up the usable volume," notes Fullerton) but spartan.

One of MOL's main purposes was to solve the problems of living in space for extended periods—problems that had not been addressed by the short Mercury and Gemini flights. "There were a lot of people when the program first started that didn't think man could survive for 30 days in space," recalls Macleay. "They thought you'd come back jelly."

The laboratory had to be self-sustaining for as long as 30 days at a time, and had to carry enough food, water, and other expendables to sustain two pilots. Early on, the MOL designers began favoring a two-gas atmosphere instead of pure oxygen for the crew to breathe, and they considered both nitrogen and helium as the second gas. Macleay remembers one of the more peculiar results of the oxygen-helium tests. If it had ended up as MOL's atmosphere, he says, "your voice was going to sound like a duck's."

In the spring of 1966, the Army Corps of Engineers acquired almost 15,000 acres of ranch land abutting Vandenberg Air Force Base for its new Space Launch Complex 6 (see "The Nine Lives of Slick Six," Feb./Mar. 1997). From SLC-6, the Air Force said, Titans could put into polar orbit vehicles weighing 15 tons—the weight of the MOL station.

And there was good news, for a change, from the defense department. McNamara told the House Armed Services Committee that MOL would get $159 million in fiscal year 1967, enough to keep things on track for a 1968 launch. Air Force pilots would be up there before NASA got to the moon.

The engineering side was looking up as well. On November 3, 1966, a Titan IIIC lifted off from Cape Kennedy carrying a modified Gemini capsule atop a mock MOL canister made from a Titan rocket stage. When the Gemini's hatch was examined after an ocean recovery, concerns about a deadly hole in the heatshield vanished. In fact, the heat of reentry had welded the customized hatch shut. MOL seemed to be well in hand.

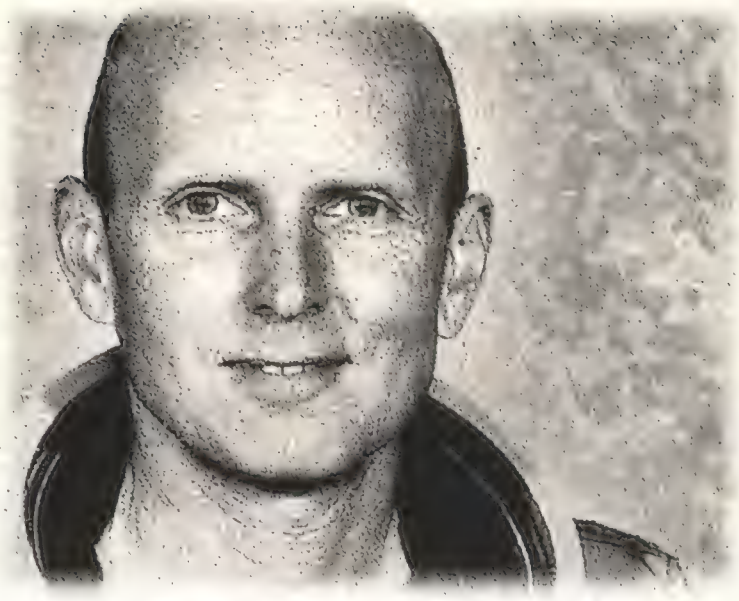
But in January 1967, a harbinger of trouble appeared. During ground tests at Cape Kennedy, a fire broke out inside the sealed Apollo 1 capsule, killing all three NASA astronauts on board. This meant a redesign for Apollo, but it also meant a costly reconfiguring of the Gemini-derived capsule used in MOL.

"The Apollo fire forced a review of all materials" for fire resistance, says Lawyer. "There was a noncompetitive redesign of the vehicle. It cost a huge amount. Indirectly, the fire on the pad had one hell of an impact."

As expensive as the Apollo fire proved to MOL, it might not have been lethal over the long pull of development. A greater hazard resulted from a shift in the political climate. Instead of Battlestar Khrushchev, along came the 1967 Outer Space Treaty, an international agreement forbidding the orbiting of weapons of mass destruction and reserving space for largely peaceful purposes. Suddenly, when it came to human activities in orbit, "military" was a dirty word.

Hartsfield: Flew three times on the shuttle

Competitors were everywhere. NASA had begun more serious work on an Apollo-derived space station as an encore to the moon landings. The Air Force had begun a clandestine effort that would evolve into the secret National Reconnaissance Office. The Discoverer and Corona satellites were already returning spy photos, and the CIA had a monster satellite called



Fullerton: Still at NASA, still flying

Hexagon—later, Big Bird—on the drawing board as an alternative to MOL. Big Bird would be as big and heavy as the Air Force system and could also carry a spy camera, but it would be man-free. The idea of losing a spacecraft without losing a life had a powerful appeal.

The MOL-men, it seemed, had only been backups. "Now it's obvious to me why we were selected," says Al Crews, a member of the first group who had transferred from Dyna-Soar. "We were told we were going to be the military space program," which meant they would be conducting experiments in orbit. "When we were selected, though, they told us we were really the manned system to operate the recon systems. If [robots] couldn't do it, they'd send us."

Mainly, there was Vietnam. What had been a minor distraction in 1963 had become a full-blown war by 1967, a conflict that ran on life, materiel, money—and fighter pilots, for whom it was a powerful magnet. The MOL astronauts felt the tug, while Pentagon and White House accountants started looking for programs they could cut to help finance the war. MOL was like a rose tree planted in the jungle—every living creature for miles around wanted a bite out of it.

By now, most of the pilots in the first two groups were migrating to Los Angeles and other points, following their assigned specialties—Fullerton, "the booster guy," to Martin Marietta in Denver, Lawyer and Macleay working on the pressure suit, Abrahamson on simulators. Everyone was detailed to some niche of MOL development. The newcomers in the third group worked on engineering evaluation, helping the engineers test different designs—"which way switches should move, stuff like that," as Herres puts it. "We heard stuff, but it was far away."

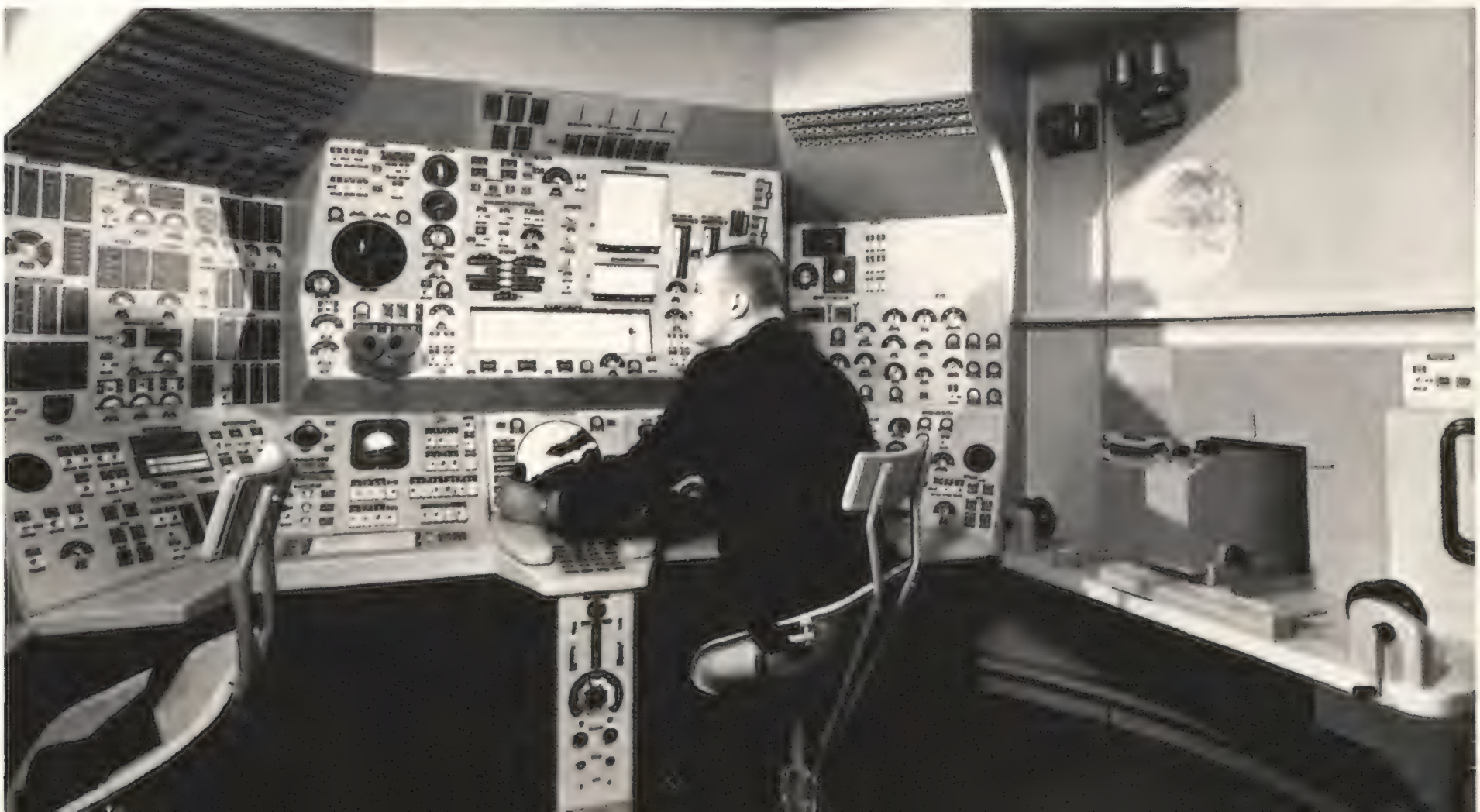
The "stuff" had to do with MOL's growing money troubles, some of which were caused by delays in developing the Titan. "Always, when you start a program," Don Peterson says, "there comes a point in time, the second or third years of the program, where there's a hump" that has to be surmounted. On MOL, he says, "the launch date was always three years away. It never really got closer." The first manned flight slipped to 1969-1970, then to 1971. Meanwhile, the $1.5 billion estimated cost of the project rose to $3 billion.

"There was still a lot of excitement" about going into space, explains Fullerton, "but the preponderance of publicity was NASA's. MOL, due to classification, couldn't argue very hard [for its existence]. We never had the sense of completeness" that Apollo had.

Jack Finley, one of the Navy pilots selected in the first MOL group, decided to bail out. "There was a war going on, and all my friends were out there doing another job," he says. "My Navy buddies, except Dick Truly, were doing their thing in the war. I was trained to try and lead people in combat." Finley left the program in 1968, and within a year or so he was flying missions over Vietnam.

By early 1969, however, the MOL community began to feel more upbeat. The crews had begun flying parabolic zero-gravity simulation flights in a KC-135 rigged with a mockup of the transfer tunnel. "We started seeing things

Spying from orbit, 1960s-style. MOL would have evaluated human camera operators, but satellites got the job instead.



COURTESY QUEST MAGAZINE

we could touch," recalls Henry Hartsfield, a member of the second group. "The pad was 90 percent completed. We were contemplating the next spring moving up to Vandenberg."

The project also seemed to have a steady financial heartbeat—the last Johnson administration budget contained $576 million for MOL. The new Nixon administration was favorably disposed toward a military presence in space, and the incoming Air Force secretary called MOL "important, even urgent." Even though the first manned launch had slipped again, this time to 1972, it wouldn't be long before the first MOL crews would be named and flight training would begin. "We all felt pretty good up to that point," recalls Al Crews.

Herres: Rose to number two job in the Pentagon

Shirley Herres remembers that she was putting up her hair on the morning of June 10, 1969, when her husband Robert suddenly appeared. "I asked him what he was doing home," she says, since the normal workday at Edwards usually went from dawn to late night. "He said he was out of a job."

Word had come down: The White House, with the budget office leading the assault, had just canceled the MOL project.

"The way the cancellation was passed to the people wasn't very nice," says Hartsfield, who was in Los Angeles at the time. "Most of us heard it on the radio going to work. I kept changing the station, hoping it would improve. At Douglas it was like walking into a morgue."

Fullerton heard the news upon landing a T-38 at Edwards. Abrahamson was at Vandenberg. Truly and Macleay were at GE's plant in Pennsylvania when, Macleay remembers, "in walks the president of General Electric and his secretary, and she's crying her eyes out, and he announces that the program's been canceled."

The cancellation surprised everyone, Air Force and contractor alike. By some estimates it killed off 10,000 jobs. But unlike the ashen, suddenly unemployed engineers at Douglas, the military pilots knew that the end of one program meant only that their careers would veer off in some new direction. In the services, you learned to expect the unexpected.

All the MOL pilots were invited by NASA to come down to Houston to interview for the astronaut corps, but an unwritten rule quickly became apparent: Those over 35 years old need not apply. Seven of the 14 surviving MOL astronauts—Truly, Crippen, Overmyer, Bobko, Fullerton, Hartsfield, and Peterson—made the cut. "It was a heartbreak for seven of us," says Crews, "but it opened a larger door for the other seven when they got to go to NASA."

"I was devastated," recalls Jim Abrahamson, who'd turned 36 in May. "I flew down to see [NASA astronaut office chief] Deke Slayton, tried to talk my way into the astronaut program." But Slayton wouldn't budge, and with good reason. He didn't have enough flight opportunities for the astronauts already in his program, and he knew it would be a long time before even the younger MOL guys went into space.

Herres says he never knew about the 35-and-under business, but he wasn't very interested anyway. "They already had 57 astronauts," he says. "I would spend ten years waiting to fly. I knew that this was the decision point for my career. I went back to the Air Force to work at Edwards."

"When the program was canceled," Hartsfield says, "most of us volunteered to go to Vietnam." But because MOL had been classified, the pilots faced a one-year restriction on duty and travel. Three of the group chose to get an advanced degree instead. "The day I was leaving L.A., I got a call," Hartsfield recalls. " 'Don't leave yet, NASA wants you.' " He went to school for a year, then over to the space agency.

Says Fullerton: "The offer seemed so unique you couldn't pass it up."

NASM

November 3, 1966: MOL's one and only test flight, on a Titan III launcher, proved the hatch design was safe.

Pondering the curious case of MOL 30 years later, one wonders whether the cause of death lay in the idea itself or in the peculiar politics of the time. "I think MOL didn't fly because you could do the job cheaper with unmanned systems," observes Don Peterson. When cameras more advanced than the KH-10 finally flew, they were on satellites, not a space station with two people on board.

But what if MOL had succeeded?

"Frankly," Abrahamson observes, "as a mission it was the single most challenging mixture of taking human beings' unique powers and combining that with computational capability and machines to make the best of both. It was a challenging experiment in that context. I thought it was absolutely inspirational." But not even he, who still says he would have traded his general's stars for a crack at spacefaring, thinks MOL would have endured.

Bob Herres echoes that sentiment, as do some of the other MOL pilots. Even if the station had reached orbit, he says, "I think we would have been canceled eventually. If we'd answered all the questions—and we could have, maybe—then it could have been different." But he doesn't believe the Air Force would have been able to hold that high ground, given the competition for money.

A final irony: All of the MOL pilots selected as NASA astronauts finally flew on the space shuttle and returned to Earth in that fast, steep dive the 17 helped pioneer all those years ago at Edwards. Had Robert Lawrence survived, he would have been one of them.

The Seventeen

The surviving MOL pilots, now in their 60s, lost little of their 30-something itch to excel. All had full and interesting careers, and all retired from military service as full colonels or better. All those who became NASA astronauts eventually flew on the space shuttle. The MOL crews were:

(Group One: Below, standing left to right)

James Taylor, deputy commandant of the Aerospace Research Pilot school, died September 4, 1970, in a T-38 crash.

Gregory Neubeck retired from the Air Force after serving as vice commander of the Tactical Air War Center at Eglin Air Force Base in Florida.

Richard Lawyer is currently director of flight operations for Tracor, a military contractor in Mojave, California.

Albert Crews was a pilot with NASA Flight Crew Operations at Johnson Space Center before retiring in 1994.

Lachlan Macleay returned to flight duty after MOL and retired from the Air Force in 1978. He lives in Oregon.

John Finley recently retired from Federal Express flight operations in Memphis, and still works in aircraft sales.

Richard Truly, a retired vice admiral, flew two shuttle missions, served as NASA Administrator, and now directs the National Renewable Energy Laboratory in Colorado.

Not pictured: **Michael Adams** transferred to the X-15 program in July 1967 and died in the catastrophic crash of the number-three airplane later that same year.

(Group Two: Below, sitting left to right)

Robert Crippen flew on STS-1, the shuttle's first orbital flight, and became director of the Kennedy Space Center. He now works for the Thiokol Corporation in Ogden, Utah.

COURTESY QUEST MAGAZINE (2)

Robert Overmyer, the only MOL Marine, was pilot on STS-5 and commander of STS-51B. On March 22, 1996, he was killed testing a Cirrus VK-30 kit plane near Duluth, Minnesota.

Karol Bobko was a pilot on shuttle mission STS-6 and commander of STS-51D and STS-51J. He now works at Booz, Allen & Hamilton in Houston.

Gordon Fullerton was a pilot for space shuttle approach and landing tests in the 1970s and flew two orbital missions, STS-3 and STS-51F. Now at NASA's Dryden center, he still flies all aircraft, great and small.

Henry Hartsfield served as pilot of STS-4 and commander of STS-41D and STS-61A. He recently retired from NASA's space station program.

(Group Three: Above, left to right)

Robert Herres was the first vice chairman of the Joint Chiefs of Staff. He retired in 1990 with four stars and is now CEO of United Services Automobile Association (USAA).

Robert Lawrence was killed in an F-104 crash at Edwards Air Force Base on December 8, 1967.

Donald Peterson flew as a mission specialist on STS-6 and now lives in Seabrook, Texas.

James Abrahamson directed the space shuttle and Strategic Defense Initiative programs, retired a three-star general, and is now chairman of International Air Safety LLC in Washington, D.C.

>SIGHTINGS<

Hiroji Kubota sailed over last year's Oshkosh, Wisconsin fly-in in the Fuji blimp to capture this panorama with a six-by nine-inch Fujika camera. "I was amused to be able to see many hundreds of all kinds of airplanes at a rather small area of the airport," he says. Kubota has logged 200 hours in the Fuji blimp (he considers the slow, stable blimp the ideal platform for aerial photography) and has shot from all sorts of aircraft, but he says he does not consider himself an aerial photographer; he usually shoots people and landscapes to capture the cultural aspects of various countries for large-

HIROJI KUBOTA/MAGNUM PHOTOS, INC.

format photography books. While working on such a book about the United States several years ago, he visited the Experimental Aircraft Association's annual Oshkosh convention and was overwhelmed by the sheer number of aircraft—11,500—and people—840,000. (This year's convention is from July 29 to August 4.) When he learned that the Fuji blimp was headed to Oshkosh '97, he signed up to shoot the event. Kubota removes a window so he can lean out for maximum coverage, but he says even with his large-format camera he can't get all the aircraft at Oshkosh in one frame.

Cub Scouts

COURTESY RINKER BUCK

Flight of Passage *by Rinker Buck. Hyperion, 1997. 351 pp., b&w photos, $23.95 (hardcover).*

Rinker Buck was 15 years old on the October day in 1965 when his brother Kernahan, a new pilot of 17, announced his plan to fly coast to coast in the family's 85-horsepower Piper Cub. The tiny two-seater had neither radio nor lights, and its navigational aids consisted of "an ancient magnetic compass bolted to the instrument panel and a shopping bag filled with airmen's charts."

Would Rink like to come along? Rink, raised on a diet of "barnstorming blarney"—their father's embroidered tales of flying the airshow circuit during the Depression—quickly said yes. *Flight of Passage* is his midlife retrospective of the brothers' cross-country jaunt.

Each boy had his own agenda for the trip. Kern, sincere, squeaky clean, the eldest of Tom Buck's 11 children, simply hoped to make a name for himself. Rink, a fun-loving discipline problem with attitude to spare, yearned to top the exploits of his father, a crackerjack pilot who "had never fulfilled his dream of flying himself across the Rockies.... I wanted to beat my father at something, and beat him good."

There was just one problem with that plan: The vintage Cub, a 1946 tailwheel classic that Tom Buck had picked up for $300 in 1963, was in no shape to fly from Basking Ridge, New Jersey, to San Diego. The boys therefore spent the winter of 1965-1966 restoring the airplane to mint condition. That salvage job keeps the Cub—and, regrettably, the story—grounded for the first third of the book.

Once the Cub "pops off the ground and claws for air," however, Buck's writing takes wing. The boys cross the Delaware River to find themselves amid "menacing and black anvil-head clouds, their tops silver-bright in the sun.... We'd come around the gauzy corners of the cloud into open skies dazzling with rainbows, sparkling fields and tidy, white-washed Pennsylvania Dutch farms."

For six July days in 1966, the brothers pushed west, redlining the airspeed indicator at 120 mph. They started early each morning, flew hard until thermals flared up in the afternoon, then wedged in a few more hours' flying time come evening.

Decked out in Ray-Bans, paisley shirts, and penny loafers, the two East Coast naïfs soon got an eyeful of hard-bitten characters from Real Life. In Indiana they fell in with a crop-dusting pilot whose face "was so burned and wrinkled by the sun that it looked like driftwood." In Arkansas they were alternately hailed as Kennedy lookalikes and mocked as "prettyboys." And at small fields everywhere, they were taken under the wing of "airport geezers": old-timers who dispensed aviation fuel and flying wisdom in equal measure.

Flight of Passage often reads like *Buzz Jobs for Dummies*. Some of the boys' low-level missions—racing a freight train across Kentucky, for example—were innocent, Norman Rockwellian affairs. Farther west, however, the young Bucks "dive-bombed" barge workers on the Mississippi and dropped Moon Pies on prairie dogs in Texas. They even swooped so low as to run a Greyhound bus off an Arizona highway.

The book's title is a nod to the rites of passage that Kern and Rink experience along the way: their first coffee, their first beer, and their first (albeit uneventful) visit to a whorehouse (they had been drawn to the establishment by its name, Motel Cheap).

Coping with crises mechanical and topographic, the boys slowly bond as brothers. By trip's end, Rink discovers, "Everything between us seemed easier... now that I wasn't wasting all my energy hoping [Kern] would change." Rink even comes to appreciate and accept his hard-driving father: "He couldn't sit in a plane without looping or rolling it and he couldn't enter a room without dominating everyone in it. So what? I could exist in a separate space from him and be whatever I wanted."

But don't read *Flight of Passage* for its obsession with family dysfunction. Instead, read it for passages of flight like this one: "In the half-light behind us, the big Pratt & Whitney radials played a

morning hymn. The gear boxes clicked, the throaty manifolds hummed, the air from the props whistled through the sprayer bars. The sound seemed to urge us west."

—Allan Fallow is an editorial director at Time-Life Education in Alexandria, Virginia.

Countdown: A History of Space Flight *by T. A. Heppenheimer. John Wiley & Sons, 1997. 398 pp., b&w photos, $30.00.*

More than 10 million pounds of thrust thundering from its thirty NK-15 engines, the massive Soviet N-1 lifted itself slowly on a shuddering, blue-white column of flame. It was the N-1's second flight, two weeks before the U.S. launch of Apollo 11 in July 1969. But when a small sliver of metal whirled into the liquid oxygen turbopump of engine number 8, "this moon rocket, fully fueled and weighing as much as a naval destroyer, fell back onto the launch complex and exploded in an enormous fireball."

This is just one of several accounts in which T.A. Heppenheimer makes use of U.S. and Russian archives unsealed since the end of the cold war.

In this informative history of 20th century rocket development and spaceflight, the author, an *Air & Space/ Smithsonian* contributor, takes us from the 1920s experiments of Robert Goddard and Valentin Glushko through Wernher von Braun's 1930s research on the A-1 series, which culminated in the A-4/V-2. He shows us the crucial role of the prematurely outdated X-10/Navaho intercontinental ramjet cruise missile, whose boosters and guidance system became prototypes for later Intercontinental Ballistic Missile powerplants and ballistic missile submarine navigation systems; the progression from X-20 to Manned Orbiting Laboratory to space shuttle; and the sad decay of once-thriving Russian launch facilities.

Nevertheless, we face puzzling omissions and the occasional error. Why, for example, excessive detail about U.S. interstate highway systems—but no mention of wartime Germany's long-range plans for the two-stage A-9/A-10 intercontinental winged rocket, or the Sänger antipodal atmospheric skip-bomber that caught Stalin's interest after World War II?

Moreover, while outlining the X-17's contributions to ablative nose cone development, Heppenheimer overlooks the rocket's now declassified 1958 discovery of the electromagnetic pulse (the Argus Effect) caused by high-altitude nuclear detonations—four years before these findings were publicly confirmed in 1962's Operation Dominic tests. Nor was the B-45 (pressed into early cold war reconnaissance duties from England) "the first production jet bomber." That distinction belongs to Germany's World War II Arado 234 Blitz.

Countdown does identify key people behind the scenes—John C. Houbolt, whose lunar orbit rendezvous concept saved years and billions of dollars in putting Americans on the moon; Roger Boisjoly and Allan J. McDonald, who knew about booster O-ring problems and begged that the *Challenger* launch be scrubbed; Linda Morabito's discovery of the first active volcanoes on another planet—to cite just a few.

Incredible detective work and ingenuity also get their due. As the North American-Rocketdyne J-2 engine (crucial to the success of our lunar landing program) underwent development, it would shut down prematurely or fail to re-start in space. Pertinent evidence kept burning up during reentry. But Marshall McClure's perceptive questions enabled engineers to solve the mystery and substitute a different kind of stainless steel for the culprit auxiliary fuel line. And we read how determination and teamwork between the stricken Apollo 13 and mission control in Houston enabled the astronauts to improvise ingenious devices to make their oxygen supply last so that they could loop around the moon and use its gravity to sling themselves home.

Chapter 10, "Electrons in the Void," is the highlight of the book. In only 32 pages, Heppenheimer offers a superb summary of U.S., Soviet/Russian, and European unmanned space programs—their successes, and what has been learned from their mistakes. It's all there, from early failures of the Ranger moon probes to an account of the Magellan's synthetic aperture radar transmissions of Venusian topography. The list of accomplishments includes the contributions made by satellites to strategic reconnaissance and civilian communications, weather reporting and forecasting, and environmental assessment.

Rather than end with a helpful analytical summary of the treasures

WARBIRD ROUNDUP

North American NA-16/AT-6/SNJ *by Dan Hagedorn. Specialty Press, 1997. 100 pp., color and b&w photos and illustrations, $16.95 (paperback).*

National Air and Space Museum archivist Dan Hagedorn has compiled an exhaustive history of one of most widely used trainer aircraft in history. The AT-6 Texan, known to the Navy and Marines as the SNJ, served in a number of other roles, including light ground attack and forward air control. Hagedorn, an authority on U.S. aircraft operated by South American air forces, also highlights the many Texans sold for export.

P-47 Thunderbolt in Detail & Scale *by Bert Kinzey. Squadron/Signal, 1998. 80 pp., color and b&w photos and illustrations, $12.95 (paperback).*

TBF & TBM Avenger in Detail & Scale *by Bert Kinzey. Squadron/Signal Press, 1997. 72 pp., color and b&w photos and illustrations, $12.95 (paperback).*

Walk Around: Allison Engined Mustangs *by Glen Phillips. Squadron/Signal, 1998. 80 pp., color and b&w photos and illustrations, $14.95 (paperback).*

These additions to the popular Detail & Scale and Walk Around series won't disappoint you: The highlights include color photos of pristinely restored aircraft. *Allison Engined Mustangs* includes color views of a rare A-36 Apache—a dive-bomber version of the Mustang—that resides at the U.S. Air Force Museum in Dayton, Ohio. The color cockpit photos in *P-47 Thunderbolt* go one better—they show an aircraft whose cockpit has remained totally original since the day it was taken out of service. *TBF & TBM Avenger* reveals that the Avenger was the Navy's first carrier-borne cargo delivery aircraft (a concept eventually known as carrier onboard delivery, or COD) and that seven people could be crammed into its fuselage (for what was surely an uncomfortable ride).

amassed in his preceding pages, Heppenheimer concludes with an extended editorial characterizing manned spaceflight as expensive and politically motivated. No matter: *Countdown* is a worthy successor to von Braun and Ordway's classic *History of Rocketry and Space Travel*—highly recommended.

—Theodore L. Gaillard Jr. is a Philadephia-based writer on technology and military issues.

ON THE TUBE

"Berlin Airlift." *The History Channel. Premieres June 21, 1998, at 9:00 p.m. EST, 10:00 p.m. PST.*

A two-hour documentary on the 50th anniversary of the resupply of Soviet-blockaded West Berlin. (See "Heroes Welcome," p. 34.)

"Wings: Eyes in the Sky." *Discovery Channel. Episode premieres June 11, 1998, at 10:00 p.m. EST.*

This new installment covers the future of unmanned reconnaissance, including the Global Hawk and Dark Star drones, as well as airborne laser-equipped aircraft.

American Eagles: A History of the United States Air Force *by Ron Dick; photographs by Dan Patterson. Howell Press (phone 804-977-4006), 1997. 456 pp., photos and paintings, $65 (hardcover).*

If you purchase only one history of the U.S. Air Force, this should be the one. A great, juicy sirloin of a book, its graphic centerpiece is the loving and crisp photographs of aircraft from the collection in the U.S. Air Force Museum, executed by the superb eye of Dan Patterson. The graphics that make this a terrific addition to any coffee table are matched by the masterful text of retired Royal Air Force Air Vice Marshall Ron Dick, a contributing editor of *Air & Space/ Smithsonian*. Not only is Dick a thorough historian, but as a former RAF officer, he brings a unique perspective, viewing the U.S. Air Force with affection yet at arm's length. Some of his observations about the practices and policies of the Eighth Air Force during its early deployment to the United Kingdom at the outset of World War II may arch some backs on this side of the Atlantic, but he has evidence on his side. And his treatment of the period between the two world wars is absolutely on the mark. Threaded throughout are individual episodes—war stories—but the literate quality of the writing is what most recommends this history.

Much of the black-and-white combat photography will be familiar, but now it can all be had in one fat package. Clustered throughout are Patterson's color portraits of the aircraft and artifacts, all of them lighted in such a way that one can barely resist the urge to reach and out and touch the metal surfaces. Patterson's detailed closeups linger over the positions of .50-caliber guns, the cockpits of fighters, the flight engineer's panel and power levers, and mementos of the Berlin Airlift. Perhaps most affecting are occasional latter-day portraits of original aircrews, survivors all, and each one with a look in the eye that says *I was there*.

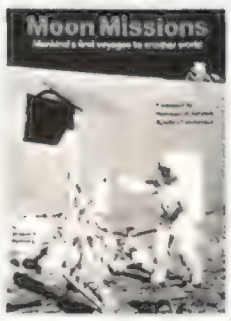
Howell Press has done its part with a fine, heavy, matte-finish stock and world-class printing that reproduces Patterson's photographs, as well as the many paintings from Keith Ferris and the Air Force collection, with the quality one expects of an art book—which this is, basically. A special $500 edition, bound in leather with a linen-covered slipcase and autographed by 40 Air Force heroes, including Chuck Yeager, Travis Hoover, Ben Davis, Leo Thorsness, and Apollo astronaut Charles Duke, is also available.

—George C. Larson is the editor of Air & Space/Smithsonian.

MOON READING

Moon Missions *by William F. Mellberg. Plymouth Press, 1997. 200 pp., b&w photos, $19.95 (paperback).*

Those searching for a more condensed account of the Apollo program can turn to *Moon Missions*, a less daunting read than Andrew Chaikin's *A Man on the Moon*. As Chaikin does, Mellberg includes an appendix that lists the particulars of each mission, but he also provides glossaries of a confusing array of NASA acronyms and terms. Foreword by Harrison H. Schmitt, the last astronaut to walk on the moon.



Hunting Down the Universe: The Missing Mass, Primordial Black Holes, and Other Dark Matters *by Michael Hawkins. Addison-Wesley, 1997. 256 pp., $24.00 (hardcover).*

In recent years, science—like art, education, and history—has been drawn into what liberals and conservatives commonly refer to as the "culture wars." A distinct offshoot of this conflict over values and politics is what you might call the "science wars." In the latter, opposing camps fall into two main factions. On one side are physical scientists and supporters from history and philosophy who hold that science is objective, yielding a real picture of nature as well as providing practices and institutions that insulate science from the messy, less precise life of the larger culture.

On the other side is a not altogether different cast of characters—sociologists, philosophers, historians, and a good many scientists (particularly those in quantum mechanics). The second camp argues that the relationship between researcher and nature is more complex—that in the process of doing science a scientist creates reality as much as understands it. With the door of objectivity ajar, science and culture necessarily interpenetrate. Politics, dispositions, and tastes—social and individual—are constant companions in the workaday world of science.

Hunting Down the Universe views this debate through author Michael Hawkins' own specialty: observational astronomy. The book's title alludes to the exacting challenges of his experimental work and the deeper philosophical question of science's ability to provide accounts of nature that may be regarded as real rather than merely hypothetical.

His research over the last two decades has focused on one of the central questions of modern cosmology and of the Big Bang theory: Only 10 percent of the universe's mass exists in the form of stars, planets, and other bodies; what and where is the rest of this mass, commonly referred to as dark matter? Hawkins' proposed answer is that numerous small black holes (the size of a double bed with the mass of Jupiter) were created soon after the Big Bang and account for most of the dark matter.

Hawkins, an astronomer at the Royal Observatory in Edinburgh, brings a vivid, worker-at-the-frontlines perspective to his story. He is an experimentalist immersed in the difficulties of collecting observational data from ground-based telescopes and of analyzing and interpreting the results. Providing an account from the "factory floor," Hawkins makes the case that the back-and-forth between experiment and theory-building in cosmology is like the old saw about

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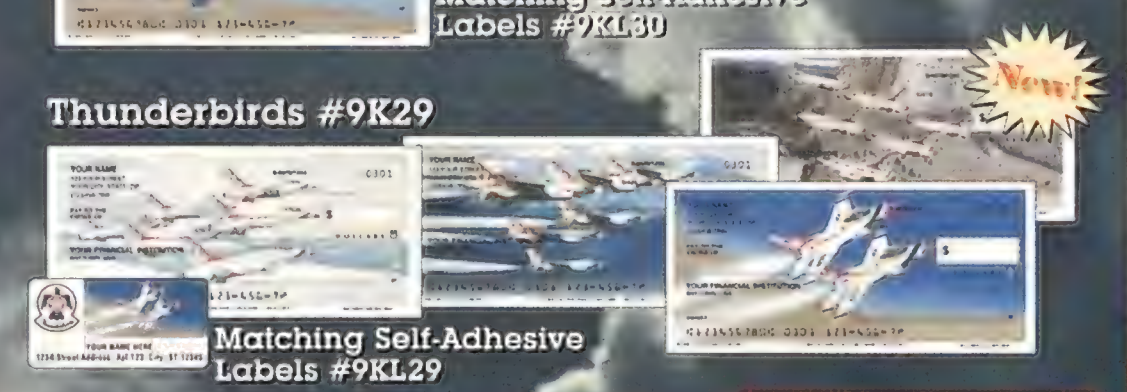

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how sausage is made—sometimes it's best not to know how science is done; the process is messier and more unpleasant than we might expect.

The first and longest part of the book is devoted to laying out the philosophical, political, and personal divisions and rivalries in the scientific and cosmological communities. Of particular interest is the author's account of how, over the last several decades, the Big Bang theory supplanted the steady-state theory as an explanation for the evolution and present state of the universe. While experimental results played an important role in this process, so did philosophical commitments, institutional politics, and personal rivalries. This exposition serves as preamble for an account of Hawkins' own research, the development in the 1980s of his theory of primordial black holes, and its reception up to the publication of this book.

In the larger context of the science wars, Hawkins' book has an ambiguous moral. His own view seems to be that in the realm of physics and astrophysics, experiment can never provide sufficient grounds for claiming that a theory presents a true picture of nature—a philosophical position with a long history—leaving an open door for non-scientific interests, political and personal, to interpenetrate the scientific enterprise. Despite this, Hawkins alternates between suggesting his own theory may represent nature truly and suggesting that it is just a convenient construct.

Perhaps this muddle is the message. Hawkins' exposition and sympathies clearly rest with the critics of science. As a scientist, he is an apostate, rejecting realism (to a point) and candidly shining a light on the workings of the inner sanctum. This is intended to be the book's appeal. In the end, though, Hawkins' image of science is still heroic. The mechanisms may be flawed, human frailties may abound, and nature's true face may be elusive, but most practitioners still strive to do honest, capable work. While such a view may leave the science wars unresolved, it does confirm that "hunting down the universe" is an uncertain, confusing affair.

—Martin Collins is a curator in the space history department of the National Air and Space Museum.

EARNING YOUR WINGS

Aviation Scholarships: Your #1 Guide to Financial Assistance for College and Flight Training *by Sedgwick D. Hines. Flight Time Publishing (phone 800-243-1515, ext. 387), 1997. 152 pp., $24.95 (paperback).*

A guide to funding available for flight training and for studying a variety of aviation disciplines, including aeronautics and astronautics, aviation maintenance, and airport administration. Also contains information on scholarships for women and minority groups.

Airline Pilot Test Kit: A Guide to Airline Pre-employment Testing *by Kit Darby. Aviation Information Resources, Inc. (phone 800-AIR-APPS), 1998. 95 pp., $35.00 members, $40 non-members (paperback).*

Includes a rundown of each airline's requirements and a selection of sample tests. Aviation Information Resources, Inc., offers a variety of guides for airline pilot hopefuls.

SEMPER FI

Marine Air Power: Real Heroes Volume III *by Randy Jolly. Aero Graphics, 1997. 192 pp., color photos, $29.95 (hardcover).*

Strap in and fly aboard a fleet of Marine aircraft, including F/A-18 Hornets, EA-6 Prowlers, AV-8 Harriers, and AH-1 Cobras.

Skywatchers, Shamans & Kings: Astronomy and the Archaeology of Power *by E.C. Krupp. John Wiley and Sons, Inc., 1997. 364 pp., $27.95 (hardcover).*

At a time when many of the planets of our solar system have come within human reach, this book provides a riveting counterpoint to the future orientation of space exploration. E.C. Krupp, author of several books on the history of celestial observation, explores here the relationship between the ability of ancient rulers to predict heavenly events and their ability to maintain dominion over their subjects.

That thesis is hardly open to doubt, as Krupp shows repeatedly in his exhaustive study of early civilizations around the globe. The greater value of *Skywatchers, Shamans & Kings* is in the wealth of detail; the book takes a close look at the many archaelogical fingerprints of cosmic powers on Earth, those physical remains of man's constant longing to understand and chart the cosmos. Mexico, China, India, Mesopotamia, Ireland, Chile, Southern Africa, California, Egypt, Siberia, Turkey, France, Bali—in all these places and more, kings, shamans, court astronomers, and other powerful persons have left evidence of this driving urge to interpret and harness the force of the heavens.

What linked prehistoric cave dwellers to more advanced cultures like the Maya and the Cambodians were observations about the seasonal renewals of food and water resources that seemed to rely on the behavior of the stars. Each civilization devised its own cosmography, or design for the universe and interpretation of man's place in it. In the most primitive societies—those of the hunter-gatherers—the regular migrations of animals represented the animals' role as hoofed intermediaries between the concreteness of Earth and the less tangible role of the skies. Established agrarian societies required celestial knowledge that would lead to prosperity through proper planting and harvesting; thus, the timing of rain itself became part of the quest for cosmic order. Rulers all over the world devised forms of architecture that could both monitor celestial events and serve as tall platforms or properly aligned shafts and hallways for closer communion with the energy of the sky. Among the fascinating histories this book relates is that of the Mongols under Genghis Khan (nicknamed "Heaven") and his grandson, Khubilai Khan, who eventually ruled over as much as a third of inhabited Earth—thanks to deeply held beliefs about cosmic order.

One of Krupp's greatest contributions is to describe many well-known and not-so-well-known early astronomical monuments: Guo Shoujing in China, Bighorn Medicine Wheel in Wyoming, Newgrange in Ireland, and so on.

Krupp gives the general reader an overview of the tribes that throughout

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October 1-11.

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Copper Canyon: Mexico's Sierra Madres
October 17-25.

Japan Journey October 27-November 6.

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October 27-November 8.

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history have tracked the stately and sometimes startling nature of cosmic change. At the same time, serious students of this topic will find ample particulars (like a 29-page bibliography containing hundreds of references) for research projects. In addition to pulling off that difficult balancing act—writing a book that appeals to different types of readers—the author has suffused his work with the force of authenticity. Krupp mentions many times that he has observed firsthand the places and phenomena he writes about. The excellent photographs and diagrams in *Skywatchers, Shamans & Kings* add enormously to the narrative. The only flaw is the small typeface, which makes reading the book sometimes a bit laborious.

—Nan Chase is a freelance writer in Boone, North Carolina.

LIBERATORS GALORE

Coffee Tower: A History of the 459th Bombardment Group in World War II *by Lyle McCarty. Turner Publishing Co. (phone 502-443-0121), 1997. 224 pp., $49.95 plus $5.00 shipping and handling (hardcover).*

This is a better effort than most unit histories—it's more than a collection of reminiscences, squadron patches, and snapshots of B-24s and their air and ground crew. There's a real story here, told in 10 readable chapters. Appendices include lots of mission statistics and an index of tail numbers and nose art.

B-24 Nose Art Name Directory *by Wallace R. Forman. Specialty Press, 1996. 189 pp., b&w photos, $19.95 plus $4.50 shipping and handling per order, (paperback).*

More than 7,800 B-24 Liberators grouped by serial number, nose art, and unit. Center section includes a photo collection.

Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Vol. II: External Relationships, *ed. by John M. Logsdon et al. NASA History Office, 1996. 636 pp., illustrations, $40.00 (hardcover).*

Anyone impressed by the outstanding quality of *Organizing for Exploration*, the first volume in the NASA History Office series titled *Exploring the Unknown*, will not be disasppointed by this sequel. Each of the three chapters begins with an informative essay followed by dozens of carefully selected documents. Brief explanatory remarks precede individual documents to help readers place them in historical context and better understand their importance. Many of the 150 documents in this volume are being published for the first time.

John Logsdon introduces Chapter One by observing that NASA's 1958 charter legislation authorized the agency to "engage in a program of international cooperation." During the next 30 years, NASA entered into agreements with more than 100 countries. Some conditions tended, however, to dampen cooperation: competition for limited payload space, reservations about the U.S. role as dominant partner, and frustration over NASA's apparent inability to sustain political and budgetary support for particular missions. In the post-Apollo era, foreign concern about the availability of U.S. launch services and U.S. fear of uncontrolled technology transfer presented further challenges to cooperation. U.S.-U.S.S.R. space relations, which historically received separate treatment in U.S. policy-making, earn Logsdon's attention as "a barometer of the overall state of relations between the two countries."

The next chapter begins with Dwayne Day's essay on the history of civilian-military relations in space. Day asserts that civilian-military cooperation in space pre-dated NASA but changed dramatically with that agency's creation. Although the military determined space priorities prior to NASA's establishment, it subsequently played a secondary role in support of civilian activity. A cost-effective military mission for humans in space proved elusive, whereas civilian manned missions flourished in pursuit of scientific objectives and national prestige. Never entirely comfortable with Department of Defense participation in NASA's space shuttle program, uniformed military officers became "highly distrustful [after the *Challenger* disaster] of any cooperative agreement foisted on them by civilians." Despite contention on the policy level, Day finds a consistent pattern of successful civilian-military cooperation on the operational level.

W. Henry Lambright highlights the third chapter with an overview of "the NASA-industry-university nexus." He reviews how this "powerful institutional partnership" came into being, reached its limits during the 1960s, and subsequently changed to meet the demands of spaceflight between the 1970s and the 1990s. Despite contractual and other problems, such innovations as the Sustaining University Program, "incentivizing" contracts, phased project planning, and research institutes kept the partnership going over the years. More recently, efforts to support private sector space initiatives have significantly affected the nexus. Lambright observes that commercialization of space and privatization of the space shuttle have significantly altered NASA-business relations.

Like its predecessor in the *Exploring the Unknown* series, this volume clearly is meant for the reference shelf rather than for casual reading. Researchers can glean much from it, and decision makers would be ill-advised to ignore it. Owners of the first two volumes undoubtedly will cheer upon learning that another will be available soon. Subtitled *Using Space*, that volume will contain essays and documents related to remote sensing of Earth, communications satellites, and commercialization.

—Rick W. Sturdevant is a senior research historian at Air Force Space Command headquarters at Peterson Air Force Base in Colorado. He is a frequent contributor to Air Force *magazine.*

NASA GRAPHICS ON LINE

Download 65 digitized drawings, graphics, and line art of aircraft that have flown at NASA's Dryden Flight Research Center at Edwards, California from the 1940s to the present:
http://www.dfrc.nasa.gov/gallery/graphics/index.html
The images are not copyrighted and are available in both EPS and GIF formats. The NASA Dryden public affairs office says that the drawings should not be assumed to be completely accurate from an engineering standpoint but are ideal for clip art or other applications. Aircraft drawings include the Convair B-58 Hustler, HL-10 lifting body, SR-71 Blackbird, and the X-1/XS-1.

CREDITS

Escape from Saigon. Richard A. Macdonald flew with VA-93 aboard the USS *Midway* from 1975 through 1978.

Walk This Way. Andrew Chaikin wrote "Fallen Arrow," which appeared in the Apr./May 1998 issue of *Air & Space/ Smithsonian*.

Higher Calling. Carl Hoffman is a frequent *Air & Space* contributor.

Further reading: *Into Thin Air*, Jon Krakauer, Villard Books, 1997.

Heroes Welcome. Linda Shiner is the executive editor of *Air & Space*.

Further reading: *Airbridge to Berlin*, D.M. Giangreco and Robert E. Griffin, Presidio Press, 1988 (excellent photographs).

Drawing the Line, Carolyn Eisenberg, Cambridge University Press, 1997.

The Berlin Candy Bomber, Gail S. Halvorsen, Horizon Publishers, 1997.

The Wall Street Decade. Bruce D. Berkowitz is a frequent contributor to *Air & Space*.

Limp Blimp. In his career as an aerospace photographer, Chad Slattery has hitched rides in some very fast aircraft, but low-and-slow blimps are his favorites.

Houston, (and Moscow, Munich, Tokyo, Montreal...) We Have a Problem. Marcia Dunn covers the space program from Cape Canaveral for a news wire service.

The 21st Century Fighter. Fred Reed is a former Marine who writes about military technology.

The Wizards of What If. George C. Larson is the editor of *Air & Space*. He worries that if Earth is ever struck by a large asteroid, the world might end before he masters the game of golf.

A Sudden Loss of Altitude. Frequent contributor Carl Posey wrote about the Brazilian space program in the Oct./Nov. 1997 issue.

Further reading: "The Manned Orbiting Laboratory," Curtis Peebles, *Spaceflight*, April 1980 and June 1980.

On Alert. Bob McCafferty served in the Strategic Air Command under General Curtis LeMay, but the only thing he ever flew was computers. He continues to claim he'll at least go to ground school someday.

CALENDAR

June 5–7
Mid Atlantic Air Museum World War II Commemorative Weekend. Win a ride in a P-51 Mustang and watch flybys of World War II bombers and fighters. Reading Regional Airport, PA, (610) 372-7333.

June 6 & 7
Rogue Valley Family Fly-In. Rogue Valley International Airport, Medford, OR, (541) 855-9036.

June 10–July 15
B-17 Wild West Tour. *Aluminum Overcast*, a restored Boeing B-17 belonging to the EAA Aviation Foundation, will make 10 stops at airports in California, Oregon, and Washington before returning to its home in Oshkosh, Wisconsin. For information on *Aluminum Overcast*'s schedule, call (920) 426-6523.

June 13
EAA Antique/Classic Chapter 7 Fly-In. Andover-Aeroflex Airport, Andover, NJ, (973) 786-5682.

Meigs Field Open House and Fly-In. Meigs Field, Chicago, IL, (773) 465-0388.

June 13 & 14
EAA Chapter 36 Fly-In. Washington County Regional Airport, Hagerstown, MD, (301) 739-0074.

Helicopter Airshow. Learn about rotary wing aviation's role in law enforcement, community safety, and search and rescue. Hansen Dam Recreation Complex, Lake View Terrace, San Fernando Valley, CA, (818) 883-9248.

Wings Over Batavia Airshow. Genesee County Airport, Batavia, NY, (607) 739-8200.

June 14
Fox Valley Sport Aviation Association-EAA Chapter 579 Fly-In. Aurora Municipal Airport, Sugar Grove, IL, (630) 466-4579.

June 18–21
American Waco Club Fly-In. Creve Coeur Airport, St. Louis, MO, (616) 624-6490.

June 19–21
Gathering of Eagles: World War I Fly-In. Gardner Municipal Airport, Gardner, KS, (913) 788-5435.

June 20 & 21
Jack B. Poage Airshow. Carroll County Regional Airport, Westminster, MD, (888) 876-7200.

Youngstown-Warren Regional Airshow. Youngstown Municipal Airport, Vienna, OH, (412) 846-9922.

June 21
Fly-In Pancake Breakfast. Schaumburg Regional Airport, Schaumburg, IL, (630) 830-0559.

June 23–26
Air Race Classic. This 2,385-mile air race for women pilots begins in Santa Fe, New Mexico, and ends in Batavia, Ohio. Stops include Midland, Texas, Woodward, Oklahoma, Ogallala, Nebraska, St. Joseph and Cape Girardeau, Missouri, and Rome, Georgia. For more information, call Pauline Glasson at (512) 289-1101.

June 25–27
Airliners International '98. Buy, swap, and sell aviation books, models, photographs, and memorabilia. Doubletree Hotel, Seattle Airport, WA, (360) 681-4671.

June 25–28
Reunion: Satan's Angels, the 475th Fighter Group of the 5th Air Force. Ambassador Hotel, Amarillo, TX, (806) 359-8894.

July 3–5
Great War Fly-In and Concourse. Creve Coeur Airport, St. Louis, MO, (314) 878-9575.

July 4
Rockport-Fulton Fourth of July Airshow. Rockport, TX, (800) 242-0071.

July 11 & 12
Northeast Fly-In Jamboree. Sponsored by the Empire State Aerosciences Museum. Schenectady County Airport, NY, (518) 377-1034.

July 17–19
Great Texas Hot Air Balloon Race. Gregg County Airport, Longview, TX, (903) 237-4000.

July 18
Lions Club Fly-In Fish Boil. Washington Island Airport, WI, (920) 847-2770.

July 18 & 19
Erie Airshow. Erie International Airport, PA, (412) 846-9922.

Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, *901 D St. SW, 10th Floor, Washington, DC 20024. Events will be listed as space allows.*

ON THE WEB SITE

BERLIN STATS AND STORIES

On a single day in April, 1949, British and U.S. aircraft carried 12,940 tons of supplies to Berlin. To learn more about the "Easter Parade" and other events that occurred during the Berlin Airlift visit the Web at www.airspacemag.com/ASM/mag/supp/jj98/berlin.html.

Face-Off

Bring the Martian landscape to your desktop and watch a mystery of science resolve itself! (www.airspacemag.com/ASM/web/site/QT/DorianFace.html)

FORECAST

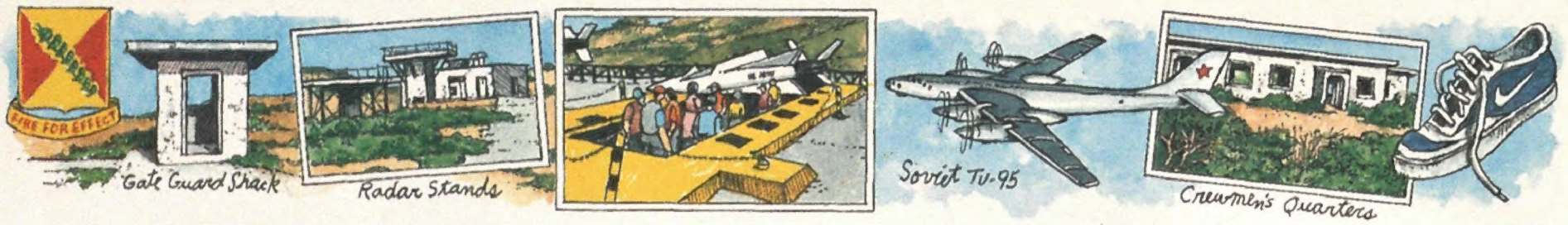
In the Wings...

Wild Weasels. The Vietnam series returns with the story of air combat's diciest mission.

Somewhere North of Dzhezkasgan. The good part about the Russian Soyuz spacecraft's parachuted return to Earth is that it doesn't need a runway. It can land anywhere. For the cosmonauts inside, that's also the bad part.

The Rescue of Eddie Rickenbacker. On the 25th anniversary of Rickenbacker's death, his biographer analyzes the country's reaction to the most harrowing ordeal of the pilot's life.

Back on the Line. After suspending production in 1986, Cessna is making light aircraft again with a new plant, a smaller run, and production teams like the Primer Yellow Dogs, the Eight Balls, and the Back of the Bus.



JOHN HEINLY

On Alert

Rod Serling would have loved it: fingers of fog creeping up steep ravines from the Pacific Ocean, slithering silently over an aging missile site.

Then, nearly 10 years after the cold war was declared over and more than 20 years after the site was last operational, a motor whirs, and a 41-foot-long missile ascends horizontally from its subterranean den. A horn sounds the alert—*ahOOOgah! ahOOOgah!*—as the weapon arcs up to an 88.5-degree angle—ready to launch.

But this missile isn't going anywhere. These days, its mission is simply to perform for tourists at Fort Barry, a decommissioned missile site in Marin County, north of San Francisco. Raised into launch position on the first Sunday of every month, the disarmed Nike Hercules serves to represent the 12 missiles that were kept on alert at Fort Barry during the cold war. At one time, there were 318 sites like this one across the United States. Then, in 1972, the United States and the Soviet Union signed the first Strategic Arms Limitation Talks agreement (SALT-I), and within a few years most Nike sites were shut down.

After it was decommissioned, SF-88L, as the Fort Barry site was known to its Army Air Defense Artillery crew, fell into disrepair. The underground magazine, or missile storage facility, was flooded with water, roofs caved in, and rust spread everywhere. In the early 1980s a group of volunteers from the Military Vehicle Collectors Club of Northern California undertook a preliminary restoration of the site. Several years later another group took up the project, led by Army Colonel Milton (Bud) Halsey. The group got a few small grants and donations but paid for most of the necessities, such as paint and preservatives, out of their own pockets.

Today, SF-88L is up and running again—the only intact Nike site the public can view. Though the site is now owned by the National Park Service, Halsey's crew does everything from repair electrical systems to cut the grass. "Historic preservation and restoration of the site is our number-one goal—stopping the rust," says Halsey, a six-foot-seven bear of a man now retired from the military. "A companion goal is bringing this stuff under control as government property [the site has 22 Nikes in various stages of completion]. The third goal is to develop an interpretation program—this is not just a boys' club to come out here and play missiles," he declares. And a fourth goal is "to teach Park Service rangers how to run this when we get old and feeble." (The service presently contributes some funding and provides demonstrations of site security, in which guard dogs go after an "intruder" in a padded suit.)

Nike Site SF-88L, Fort Barry, Golden Gate National Recreation Area, Marin County, CA. For directions phone (415) 331-1453 or visit the Nike Site home page at www.nikemissile.org. *Open Mon.–Fri. and first Sun. of the month, 12:30–3:30 p.m. Admission free.*

Halsey never worked with Nikes, but he has an encyclopedic knowledge of—and a soft spot for—the Nike system. He explains that the Nike, named for the Greek goddess of victory, was developed to deter an attack on the United States by long-range Russian bombers, such as the Tu-95 Bear. The first incarnation, the Nike Ajax, was operational by 1954. The later Nike Hercules, some of which were armed with nuclear warheads, could achieve a speed of Mach 3.65 and hit an aircraft at a range of 90 miles and an altitude of 150,000 feet. During training firings—the only occasions on which Nikes were launched—the missiles hit their targets 95 percent of the time.

Visitors to SF-88L start their tour at the sentry post, where a security guard stood watch around the clock. Next stop is a typical launch control trailer—a mobile unit where the officer in charge would prepare missiles for launch if ordered to do so. Nearby are two vans that received signals from the site's radar units. During a launch, each radar had its own mission. Acquisition radar units found aircraft in the area, both friend and foe, while the other radars had different responsibilities: tracking a target, tracking a missile, or separating a target's signal from an enemy's jamming signals. The acquisition radar's signals were sent directly to the Battery Command van, where an officer stood ready to direct an air engagement. The other radars' signals went to the Radar Control van. As they look around the vans today, younger visitors will see something they may never have seen before: vacuum tubes. The technology seems archaic now, but it at least had the advantage of being virtually impervious to the pulses of electromagnetic energy produced by nuclear explosions.

The two trailers were originally located near the radars themselves, up on Wolf Ridge, a thousand yards from the missile magazine. If the radar units had been closer, they wouldn't have been able to keep up with the missiles. For display purposes, the trailers have been moved near the launchers.

Then it's on to an open elevator where visitors can take a ride next to a restored Nike as it descends into the underground portion of the site, where the missiles were stored and where most of the Nike crew members worked. The conditions in "the pit," as the crew called it, could be grueling. When the site went on an alert, recalls volunteer Ron Parshall, a former SF-88L crew member, "you had to be here night and day. Sleep in the little ready room in your clothes. There were two launcher crews—14 to 18 men and only four bunks, so you didn't do much sleeping." And security was tight. "Even when you left the Army," he says, "you couldn't tell anyone what you were doing."

Today, visitors to the site are encouraged to ask all kinds of questions. Periodically, a child will come up with one that reminds adults why museums are needed. "Why," the young visitor will ask, "would they name a missile after a sneaker company?"

—Bob McCafferty

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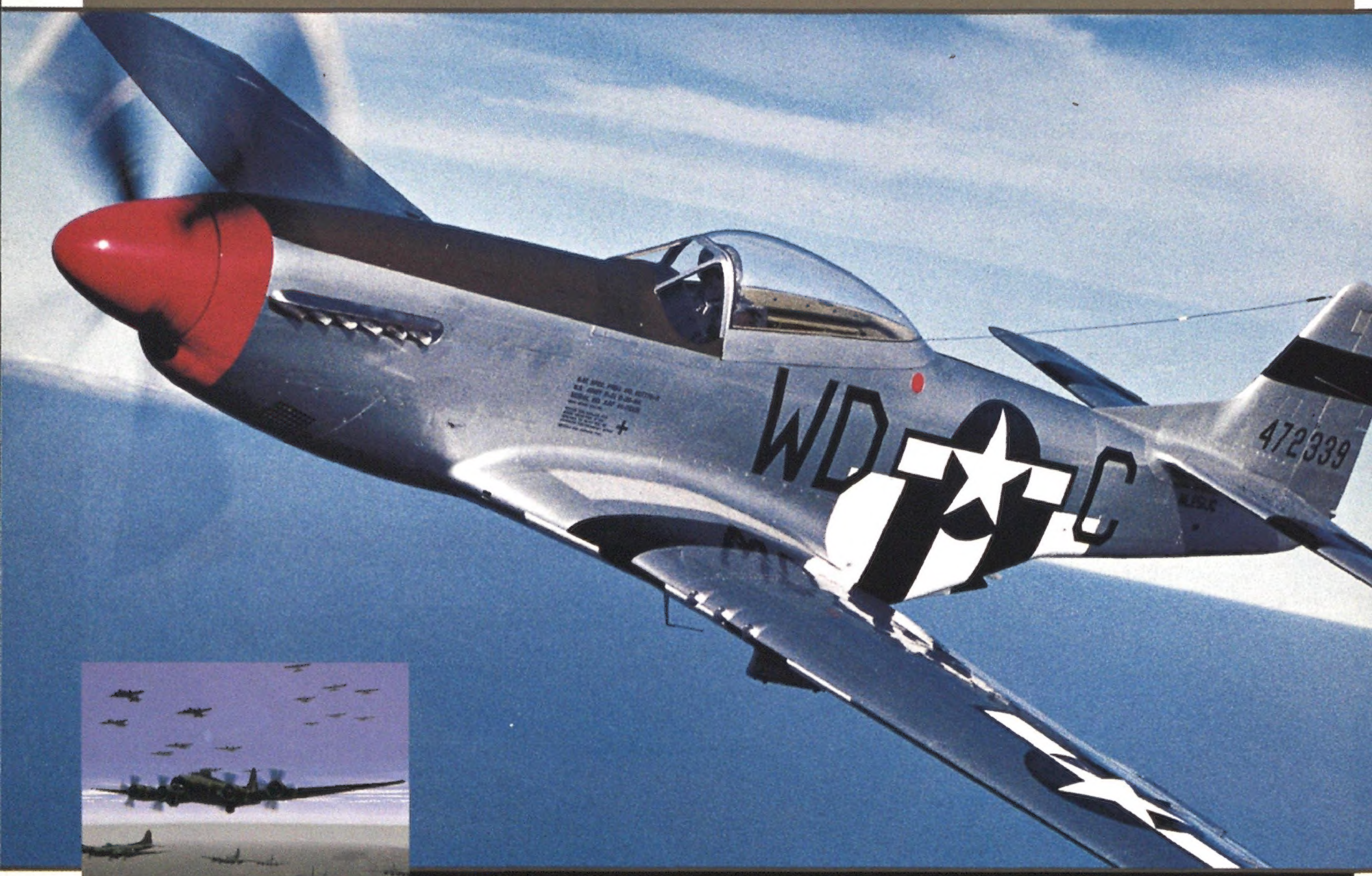

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